OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL COVER SHEET
Complete Only Applicable Items

2. ☒ Analysis — Check all that apply

Type of Analysis	☐ Engineering ☒ Performance Assessment ☐ Scientific
Intended Use of Analysis	☐ Input to Calculation ☒ Input to another Analysis or Model ☐ Input to Technical Document ☒ Input to Other Technical Products

Describe use:

Select FEPs important for TSPA modeling of the EBS.

3. ☐ Model — Check all that apply

Type of Model	☐ Conceptual Model ☐ Abstraction Model ☐ Mathematical Model ☐ System Model ☐ Process Model
Intended Use of Model	☐ Input to Calculation ☐ Input to another Model or Analysis ☐ Input to Technical Document ☐ Input to Other Technical Products

Describe use:

4. Title:

EBS FEPs/Degradation Modes Abstraction

5. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-WIS-PA-000002 REV 00

6. Total Attachments:

0

7. Attachment Numbers - No. of Pages in Each:

N/A

		Printed Name	Signature	Date
8.	Originator	Peter K. Mast	Pt K. Mast	4/12/00
9.	Checker	F. J. Pearson	Robert MacKinnon for FJP	4/12/00
10.	Lead/Supervisor	E. J. Nowak	Robert MacKinnon EJN	4/14/00
11.	Responsible Manager	Robert J. MacKinnon	Robert MacKinnon	4/14/00

12. Remarks:

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL REVISION RECORD
Complete Only Applicable Items

2. Analysis or Model Title:

EBS FEPs/Degradation Modes Abstraction

3. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-WIS-PA-000002 REV00

4. Revision/Change No.	5. Description of Revision/Change
00	Initial Issue

CONTENTS

TABLES

Page

ACRONYMS AND ABBREVIATIONS

Acronyms

AMR	Analysis Modeling Report
CFR	Code of Federal Regulations
CLST	Container Life and Source Term
CRWMS	Civilian Radioactive Waste Management System
CSNF	Commercial Spent Nuclear Fuel
DHLW	Defense High Level Waste
DSNF	Defense Spent Nuclear Fuel
DOE	United States Department of Energy
DRKBA	Discrete Region Key Block Analysis
EBS	Engineered Barrier System
ENFE	Evolution of the Near-Field Environment
EPA	United States Environmental Protection Agency
FEPs	Features, Events, and Processes
FR	Federal Register
HLW	High-Level Waste
IA	Igneous Activity
IRSR	Integration Issue Resolution Status Report
LADS	License Application Design Selection
M&O	Management & Operating (Contractor)
NEA	Nuclear Energy Agency of the Organisation for Economic Co-Operation and Development
NFE	Near-Field Environment
NRC	U.S. Nuclear Regulatory Commission
OECD	Organization for Economic Co-Operation and Development
OCRWM	Office of Civilian Radioactive Waste Management
PMR	Process Modeling Report
QAP	Quality Assurance Procedure
QARD	Quality Assurance Requirements and Description
RDTME	Repository Design and Thermal-Mechanical Effects
RT	Radionuclide Transport
SDS	Structural Deformation and Sesmicity
SZ	Saturated Zone
TBV	To-be Verified
TEF	Thermal Effects on Flow
TSPA	Total System Performance Assessment
TSPA-SR	Total System Performance Assessment Site Recommendation
UDEC	Universal Distinct Element Code
USFIC	Unsaturated and Saturated Flow Under Isothermal Conditions
UZ	Unsaturated Zone
YMP	Yucca Mountain Project
WF	Waste Form
WIPP	Waste Isolation Pilot Plant

WP	Waste Package

Abbreviations

Ka	thousand years (before present)
km	kilometer
k.y.	thousand years (duration)
m	meter
Ma	million years (before present)
M_L	earthquake magnitude
mm	millimeters
MPa	mega Pascals (a unit of pressure)
MWm^{-2}	megawatts/meter^2 (a unit of heat flux)
m.y.	million years (duration)
yr	year

1. PURPOSE

Under the provisions of the U.S. Department of Energy's (DOE's) *Revised Interim Guidance Pending Issuance of New U. S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999,) for Yucca Mountain*, *Nevada* (Dyer 1999; and herein referred to as DOE's interim guidance), the DOE must provide a reasonable assurance that the regulatory-specified performance objectives for the Yucca Mountain project can be achieved for a 10,000-year post-closure period. This assurance must be demonstrated in the form of a performance assessment that: (1) identifies the features, events, and processes (FEPs) that might affect the performance of the geologic repository; (2) examines the effects of such FEPs on the performance of the geologic repository; (3) estimates the expected annual dose to a specified nearby population group. The performance assessment must also provide the technical basis for inclusion or exclusion of specific FEPs.

Although the NRC has not defined or used the term "scenario" in the pertinent regulations, the Yucca Mountain Total System Performance Assessment (TSPA) has chosen to satisfy the above-stated performance assessment requirements by adopting a scenario development process. This decision was made based on the Yucca Mountain TSPA adopting a definition of "scenario" as not being limited to a single, deterministic future of the system, but rather as a set of similar futures that share common FEPs. The DOE has chosen to adopt a scenario development process based on the methodology developed by Cranwell et al. (1990) for the NRC. The first step of this process is the identification of FEPs potentially relevant to the performance of the Yucca Mountain repository; the second step includes the screening of each FEP.

The primary purpose of this Analysis/Model Report (AMR) is to identify and document the analysis, screening decision, and Total System Performance Assessment (TSPA) disposition or screening argument for each of the 84 FEPs that have been identified as Engineering Barrier System (EBS) FEPs (described in Section 1.1). The screening decisions, and associated TSPA disposition or screening argument, for the subject FEPs will be catalogued separately in a project-specific FEPs database (see Section 1.4). This AMR and the database are being used to document information related to the FEPs screening decisions and associated screening argument and to assist reviewers during the license review process.

1.1 SCOPE

This AMR has been prepared to satisfy the FEP screening documentation requirements in the Work Scope/Objectives/Tasks section of the development plan entitled *EBS FEPs/Degradation Modes Abstraction* (CRWMS M&O 1999a).

The current FEPs list consists of 1786 entries (as described in Section 1.2). The FEPs have been classified as Primary and Secondary FEPs (as described in Section 1.2) and have been assigned to various Process Modeling Reports (PMRs). The assignments were based on the nature of the FEPs so that the analysis and resolution for screening decisions reside with the subject-matter experts in the relevant disciplines. The resolution of other than EBS FEPs is documented in

AMRs prepared by the responsible PMR groups. Several relevant FEPs do not fit neatly into the existing PMR structure. Criticality is the largest example, and is treated in FEP assignments as if it were a separate PMR. Some FEPs were best assigned to the TSPA itself (i.e., system-level FEPs), rather than to its component models.

This AMR addresses the 84 Primary FEPs that have been identified as EBS FEPs. These FEPs represent the key features of the EBS, processes that result in degradation of these features, and processes that occur within the EBS that influence other aspects of the repository. The 84 Primary EBS FEPs addressed in this AMR are provided in Table 1

Table 1. Primary EBS FEPs

FEP Name - YMP FEP #
Excavation/Construction – YMP 1.1.02.00.00
Site Flooding (During Construction and Operation) – YMP 1.1.02.01.00
Effects of Preclosure Ventilation – YMP 1.1.02.02.00
Undesirable Materials Left – YMP 1.1.02.03.00
Error in Waste or Backfill Emplacement – YMP 1.1.03.01.00
Repository Design – YMP 1.1.07.00.00
Quality Control – YMP 1.1.08.00.00
Accidents and Unplanned Events During Operation – YMP 1.1.12.01.00
Retrievability – YMP 1.1.13.00.00
Igneous Intrusion into Repository – YMP 1.2.04.03.00
Corrosion of Waste Containers – YMP 2.1.03.01.00
Container Healing – YMP 2.1.03.10.00
Container Failure (Long-term) – YMP 2.1.03.12.00
Preferential Pathways in the Backfill – YMP 2.1.04.01.00
Physical and Chemical Properties of Backfill – YMP 2.1.04.02.00
Erosion or Dissolution of Backfill – YMP 2.1.04.03.00
Mechanical Effects of Backfill – YMP 2.1.04.04.00
Backfill Evolution - YMP 2.1.04.05.00
Properties of Bentonite – YMP 2.1.04.06.00
Buffer Characteristics – YMP 2.1.04.07.00
Diffusion in Backfill – YMP 2.1.04.08.00
Radionuclide Transport Through Backfill – YMP 2.1.04.09.00
Degradation of Cementitious Materials in Drift – YMP 2.1.06.01.00
Effects of Rock Reinforcement Materials – YMP 2.1.06.02.00
Degradation of the Liner – YMP 2.1.06.03.00
Flow Through the Liner – YMP 2.1.06.04.00
Degradation of Invert and Pedestal – YMP 2.1.06.05.00

Table 1. Primary EBS FEPs – Continued

FEP Name - YMP FEP #
Effects and Degradation of Drip Shield – YMP 2.1.06.06.00
Effects at Material Interfaces – YMP 2.1.06.07.00
Rockfall (Large Block) – YMP 2.1.07.01.00
Mechanical Degradation or Collapse of Drift – YMP 2.1.07.02.00
Movement of Containers – YMP 2.1.07.03.00
Hydrostatic Pressure on Container – YMP 2.1.07.04.00
Creeping of Metallic Materials in the EBS – YMP 2.1.07.05.00
Floor Buckling – YMP 2.1.07.06.00
Increased Unsaturated Water Flux at the Repository – YMP 2.1.08.01.00
Enhanced Influx (Philip's Drip) – YMP 2.1.08.02.00
Condensation Forms on Backs of Drifts – YMP 2.1.08.04.00
Flow Through Invert – YMP 2.1.08.05.00
Wicking in Waste and EBS – YMP 2.1.08.06.00
Pathways for Unsaturated Flow and Transport in the Waste and EBS – YMP 2.1.08.07.00
Induced Hydrological Changes in the Waste and EBS – YMP 2.1.08.08.00
Saturated Groundwater Flow in Waste and EBS – YMP 2.1.08.09.00
Resaturation of Repository – YMP 2.1.08.11.00
Properties of the Potential Carrier Plume in the Waste and EBS – YMP 2.1.09.01.00
Interaction with Corrosion Products – YMP 2.1.09.02.00
In-drift Sorption – YMP 2.1.09.05.00
Reduction-oxidation Potential in Waste and EBS – YMP 2.1.09.06.00
Reaction Kinetics in Waste and EBS – YMP 2.1.09.07.00
Chemical Gradients/Enhanced Diffusion in Waste and EBS – YMP 2.1.09.08.00
Waste-Rock Contact – YMP 2.1.09.11.00
Rind (Altered Zone) Formation in Waste, EBS, and Adjacent Rock – YMP 2.1.09.12.00
Complexation by Organics in Waste and EBS – YMP 2.1.09.13.00
Colloid Formation in Waste and EBS – YMP 2.1.09.14.00
Formation of True Colloids in Waste and EBS – YMP 2.1.09.15.00
Formation of Pseudo-colloids (Natural) in Waste and EBS – YMP 2.1.09.16.00
Formation of Pseudo-colloids (Corrosion Products) in Waste and EBS – YMP 2.1.09.17.00
Microbial Colloid Transport in the Waste and EBS – YMP 2.1.09.18.00
Colloid Transport and Sorption in the Waste and EBS – YMP 2.1.09.19.00
Colloid Filtration in the Waste and EBS – YMP 2.1.09.20.00
Suspensions of Particles Larger than Colloids – YMP 2.1.09.21.00
Biological Activity in Waste and EBS – YMP 2.1.10.01.00
Heat Output / Temperature in Waste and EBS – YMP 2.1.11.01.00
Exothermic Reactions in Waste and EBS – YMP 2.1.11.03.00

Table 1. Primary EBS FEPs – Continued

FEP Name - YMP FEP #
Temperature Effects / Coupled Processes in Waste and EBS – YMP 2.1.11.04.00
Differing Thermal Expansion of Repository Components – YMP 2.1.11.05.00
Thermally-induced Stress Changes in Waste and EBS – YMP 2.1.11.07.00
Thermal Effects: Chemical and Microbiological Changes in the Waste and EBS – YMP 2.1.11.08.00
Thermal Effects on Liquid or Two-phase Fluid Flow in the Waste and EBS – YMP 2.1.11.09.00
Thermal Effects on Diffusion (Soret effect) in Waste and EBS – YMP 2.1.11.10.00
Gas Generation – YMP 2.1.12.01.00
Gas Generation (He) from Fuel Decay – YMP 2.1.12.02.00
Gas Generation (H2) from Metal Corrosion – YMP 2.1.12.03.00
Gas Generation (CO2, CH4, H2S) from Microbial Degradation – YMP 2.1.12.04.00
Gas Generation from Concrete – YMP 2.1.12.05.00
Gas Transport in Waste and EBS – YMP 2.1.12.06.00
Radioactive Gases in Waste and EBS – YMP 2.1.12.07.00
Gas Explosions – YMP 2.1.12.08.00
Radiolysis – YMP 2.1.13.01.00
Radiation Damage in Waste and EBS – YMP 2.1.13.02.00
Mutation – YMP 2.1.13.03.00
Episodic / Pulse Release from Repository – YMP 2.2.07.06.00
Redissolution of Precipitates Directs More Corrosive Fluids to Containers – YMP 2.2.08.04.00
Gas Pressure Effects – YMP 2.2.11.02.00

A separate, independent evaluation of EBS FEPs was performed by the EBS process modeling organization (EBSO) at the Yucca Mountain Project (CRWMS M&O 2000c). The resulting AMR identified 37 FEPs (including 5 common mode events) relevant to the EBS. These FEPs are listed in table 2. These FEPs will also be considered herein.

Table 2. EBS FEPs Developed by Project

FEP ebs #	FEP Name	Issues(s)
1	Pedestal Collapse	The waste package, as a result of pedestal collapse, lies on or in the invert and could be in contact with the drip shield and the rails, and be exposed to contact corrosion. While bedded in the invert, the waste package is more likely to see local ponding and the enhanced corrosion and mobilization which might accompany it.
2	Drip Shield	Liquid water contact with the waste package is believed to affect the rate of corrosion of the metals, exposing the waste. The drip shield is intended to reduce direct liquid contact with the containers.
3	Drip Shield Supports	Failure of the drip shield supports allows the drip shield to make contact with the waste package or with the rails. Since the drip shield is made of Ti, the rails of steel, and the waste packages of a high-nickel alloy, contact could result in contact corrosion possibly affecting the integrity of the waste package.
4	Backfill	Crushed Rock is placed to protect the waste package, or the drip shield and waste package from rockfall, failure of ground support, and possibly as a Richard's barrier for

Table 2. EBS FEPs Developed by Project – Continued

FEP ebs #	FEP Name	Issues(s)
		flow. Location of backfill, the size, and material type, all affect water chemistry (and the corrosion rates for drip shield and waste packages, dissolution rates for waste), and thermal properties (and waste temperatures and cladding failure). Suggestions for material type currently include sand, crushed limestone, marble, and crushed tuff. The last is the subject of investigation.
5	Invert	The invert materials, currently expected to be crushed rock, form the bed for the rails and will be the resting place for the waste package after the support pedestals fail. The invert is part of the flow pathway from the waste to the drift bottom and exit from the drift. The invert is also part of the flow pathway for water deflected by the drip shield from the waste packages. Water can accumulate in the invert, acting as a water vapor source for corrosion or possibly ponding. Accordingly, invert materials affect water chemistry for transport.
6	Rockfall Loading Distortion of Drip Shield	Contact corrosion, compromising the drip shield or the waste package develops as a result of displacement or distortion of the drip shield.
7	Rails	Rails represent a material, steel, added to the repository which is not necessary to long-term isolation, but which may have an impact on corrosion of the drip shield and on water chemistry for transport. If the Ti drip shield and the steel rails are in contact, contact corrosion is expected, which could affect the long-term ability of the drip shield to divert water from the waste package. Such contact would be expected locally as a result of a seismic disturbance, rockfall, or ground support failure.
8	Pedestal	The pedestal may be distorted or rack because of floor heave (thermo-mechanical stress adjustment) and ground motion (seismic event), or may fail due to corrosion. Failure by any mode will drop the waste package onto or into the invert.
9	Ground Motion	Ground motion, generated by seismic events, provides accelerations to components of the repository, including the waste packages, drip shield, surrounding rock, and ground support. These accelerations cause relative motion of the components and could generate ground support failure, rockfall, and damage to waste packages and drip shields.
10	Drip Shield Movement Relative to Waste Packages/Rails	Contact of the Ti drip shield with the waste package or with the steel rails will cause contact corrosion. In the former case, corrosion of the waste package will be enhanced, while in the latter case, that of the drip shield will be accelerated. Presumably, the fate of the rails is inconsequential.
11	Relative Seismic Displacement	A seismic event in the potential repository generates relative displacements between waste package, drip shield, and rails, and ground support failure, and rockfall.
12	Ground Support Failure	Failure of ground support, for whatever reason, allows rockfall, displacement of waste packages, and development of new flow pathways. Possible cases include ground motion, thermo-mechanical stress adjustment and corrosion.
13	Thermo-Mechanical Evolution of a Repository Block	Thermo-mechanical coupling, which alters the stress state of the rock surrounding the repository, affects floor buckling, fracture sealing and openings to the EBS, and loading and unloading of ground support.
14	Shear Fracture/ Fault Movement and Relaxation	Fractures that might otherwise be closed during the thermal period, because of compression from thermal expansion, are maintained as open pathways because of shear movement. Movement also allows distortion of the drift and the relative location of drip shield, rails, and waste packages, with possible contact being established.
15	Condensation Beneath Drip Shield	Condensation on the inner surface of the drip shield circumvents its performance and provides water to drip onto the waste package and its supporting pedestal. Enhanced corrosion of waste package and pedestal becomes possible.
16	Reflux Drainage of Condensate Zone	Condensate zones could contain a substantial amount of mobile water able to flow back into the drifts, perhaps as a single extended episode.
17	Flow along Drip Shield (inside) Wall	Water vapor is available from water otherwise diverted from the waste packages, which flows down the drip shield and enters the invert, where it may accumulate.
18	Flow Through Backfill	Flow through the backfill reacts chemically with the backfill. This chemically altered water then interacts with the drip shield and rails to eventually reach the invert.
19	Movement of Backfill Through Gaps and Separations in Drip Shield	The continuity of the drip shield and its ability to deflect liquid water could be compromised as a result of movement produced by thermo-mechanical or seismic processes.
20	Fluid Flow into Gaps and	The ability of the drip shield to deflect liquid water could be compromised as a result of

Table 2. EBS FEPs Developed by Project – Continued

FEP ebs #	FEP Name	Issues(s)
	Separations in Drip Shield	the movement of liquid water through gaps or spaces which develop between drip shield segments.
21	Ground Support – Wire Mesh and Rockbolts	The expected life of ground support after the operational phase of the repository is unknown. Failure of ground support allows rockfall and development of a chimney or enlarged drift and filling of fracture or fault zones.
22	Ground Support – Rockbolts and Grout	The issues are that ground support introduces materials (Fe, grout, etc.) into the facility, which affects water chemistry. All ground support eventually fails, allowing rockfall, altering drift size and properties, and affecting flow pathways.
23	Drains (if used)	Water accumulation in the drift would wet the invert materials, possibly pond, and provide a continuing source of water vapor beneath the drip shield and backfill for interaction with waste packages and their supports.
24	Flow Along Drip Shield (outside) Wall	Since the segmented drip shield will see liquid water, the concerns are the effectiveness of the diversion (i.e., will liquid flow pass through the overlaps) and the corrosion resistance of the drip shield material to the water chemistry in the impinging water.
25	Microbial Activity	The concern is microbially accelerated corrosion and mobilization occurring in the warm, moist environment of the EBS.
26	Rockbolt/Grout Corrosion	The corrosion and alteration changes the flow path for water entrance and alters the chemistry of the water following those flow paths.
27	Drainage with Transport – Sealing and Plugging	Normal functioning of drainage in the drifts is not established, so how drainage will change if fractures are plugged is unclear. Suggestions include ponding until fractures in the wall are reached by the water level or until there is sufficient head to clear the fractures.
28	Drainage – Through Constructed Drains	Water accumulation would be possible in a drift, particularly in a region of floor buckling, if normal drainage is blocked. Such blockage could occur if fines and debris are deposited in fractures or as sediment along the drift floor. Excess water could allow more rapid corrosion and contaminant mobilization. The conundrum here is that rapid draining of water sooner might also mean rapid draining of contaminated water later.
29	Drainage with Transport – Ponding	Water could accumulate in the invert in sufficient amounts to flood the waste package, enhancing corrosion and eventual mobilization. Criticality could be a possible consequence.
30	Drip Shield Corrosion – Flow of Backfill Through Corroded Elements	The continuity of the drip shield and its ability to deflect liquid water could be compromised as a result of holes produced by corrosion.
31	Drip Shield Corrosion – Fluid Flow Through Corroded Elements to Waste Packages	Deflection of liquid water away from the waste packages depends on continuity of the drip shield and the absence of penetrations.
32	Corrosion of Drip Shields and Waste Packages	Corrosion may contribute to waste package failure. Corrosion is most likely to occur at locations where water drips on the waste packages, but other mechanisms should be considered.
33	Local, disruptive ground motion is produced by an earthquake occurring outside the potential repository	Local, disruptive ground motion is produced by an earthquake occurring outside the potential repository
34	Faulting or movement on an existing fault occurs through the potential repository	Faulting or movement on an existing fault occurs through the potential repository
35	Thermo- chemical alteration of glasses to clays and zeolites, in this unit beneath the potential repository, accompanied by volume increases which appear at the nearest free	Thermo- chemical alteration of glasses to clays and zeolites, in this unit beneath the potential repository, accompanied by volume increases which appear at the nearest free surface, namely the drift floors.

Table 2. EBS FEPs Developed by Project – Continued

FEP ebs #	FEP Name	Issues(s)
	surface, namely the drift floors.	
36	A basaltic intrusion intersects potential repository drifts and may reach the surface. EBS design and performance is of little significance for this occurrence.	A basaltic intrusion intersects potential repository drifts and may reach the surface. EBS design and performance is of little significance for this occurrence.
37	Stress alteration, increase, and relaxation during repository life causes massive failure of ground support, initiating a sequence of associated failures	Stress alteration, increase, and relaxation during repository life causes massive failure of ground support, initiating a sequence of associated failures

Note: FEPs ebs # 33-37 were not numbered in CRWMS M&O 2000c

1.2 FEPs IDENTIFICATION AND ANALYSIS

For the YMP TSPA, a scenario is defined as a subset of the set of all possible futures of the engineered barrier system that contains the futures resulting from a specific combination of FEPs. The first step of the scenario development process is the identification of FEPs potentially relevant to the performance of the Yucca Mountain repository. The most current list of FEPs is contained in the YMP FEPs database (CRWMS M&O 1999c). A comprehensive discussion of the origin of these FEPs, their organization, and their assignment to the various PMRs is provided in the documentation accompanying the database (CRWMS M&O 1999c). A brief summary of that discussion follows.

The initial set of FEPs was created for the Yucca Mountain TSPA by combining lists of FEPs previously identified as relevant to the Yucca Mountain Project (YMP) (e.g., *Total System Performance Assessment-1995: An Evaluation of the Potential Yucca Mountain Repository*, CRWMS M&O 1995a) with a draft FEP list compiled by the Nuclear Energy Agency (NEA) of the Organization for Economic Co-Operation and Development (OECD) (Safety Assessment Management 1997). The NEA list is maintained as an electronic FEP database and is the most comprehensive list available internationally. The list currently contains 1261 FEPs from Canadian, Swiss, and Swedish spent-fuel programs, intermediate and low-level waste programs of the U.K., and the US Waste Isolation Pilot Plant (WIPP) program. An additional 292 FEPs have been identified from YMP literature and site studies, and 82 FEPs have been identified during YMP project staff workshops. These FEPs are organized under 151 categories, based on NEA category headings, resulting in a total of 1786 entries. Consistent with the diverse backgrounds of the programs contributing FEPs lists, FEPs have been identified by a variety of methods, including expert judgement, informal elicitation, event tree analysis, stakeholder review, and regulatory stipulation. All potentially relevant FEPs have been included, regardless of origin. This approach has led to considerable redundancy in the FEP list, because the same FEPs are frequently identified by multiple sources, but it also ensures that a comprehensive review of narrowly defined FEPs will be performed. The FEPs list (CRWMS M&O 1999c) is considered open and will continue to grow as additional FEPs are identified.

Under the definition adopted for the Yucca Mountain TSPA, a scenario is defined as a subset of the set of all possible futures of the engineered barrier system that contains the futures resulting from a specific combination of FEPs. There is no uniquely correct level of detail at which to define scenarios or FEPs. Decisions regarding the appropriate level of resolution for the analysis are made based on consideration of the importance of the scenario in its effect on overall performance and the resolution desired in the results. The number and breadth of scenarios depend on the resolution at which the FEPs have been defined: coarsely defined FEPs result in fewer, broad scenarios, whereas narrowly defined FEPs result in many narrow scenarios. For efficiency, both FEPs and scenarios should be aggregated at the coarsest level at which a technically sound argument can be made that is adequate for the purposes of the analysis.

Consequently, each FEP has been identified as either a Primary or Secondary FEP. Primary FEPs are those FEPs for which the project proposes to develop detailed screening arguments. The classification and description of Primary FEPs strives to capture the essence of all the Secondary FEPs that map to the primary. For example, the Primary FEP "Physical and Chemical Properties of Backfill" can be used appropriately to resolve multiple and redundant Secondary FEPs that address various aspects of the backfill properties and their impact on groundwater flow and radionuclide transport at YMP. By working to the Primary FEP description, the subject matter experts assigned to the Primary FEP address all relevant Secondary FEPs, and arguments for Secondary FEPs can be rolled into the Primary FEP analysis. Secondary FEPs are either FEPs that are completely redundant or that can be aggregated into a single Primary FEP.

To perform the screening and analysis, the FEPs have been assigned based on the PMR structure so that the analysis, screening decision, and TSPA disposition reside with the subject matter experts in the relevant disciplines. The TSPA recognizes that FEPs have the potential to affect multiple facets of the project, may be relevant to more than one PMR, or may not fit neatly within the PMR structure. For example, many FEPs affect waste form (WF), waste package (WP), and the EBS. Rather than create multiple separate FEPs, the FEPs have been assigned, as applicable, to one or more process modeling groups, which are responsible for the AMRs.

At least two approaches have been used to resolve overlap and interface problems of multiple assigned FEPs. FEP owners from different process modeling groups may decide that only one PMR will address all aspects of the FEP, including those relevant to other PMRs. Alternatively, FEP owners may each address only those aspects of the FEP relevant to their area. In either case, the FEP AMR produced by each process modeling group lists the FEP and summarizes the screening result, citing the appropriate work in related AMRs as needed.

This AMR addresses the 84 FEPs that have been identified as Primary EBS FEPs, as discussed in CRWMS M&O 1999c. In addition, the 37 EBS FEPs identified internal to the project (CRWMS M&O 2000c) are also addressed. In those cases where the FEP is relevant to other process modeling groups, only the relevance of the FEP to the EBS is discussed herein. Overlap with other process modeling groups occurs for the following areas; WF degradation (CRWMS M&O 2000x), WP degradation (CRWMS M&O 2000dd), tectonics evaluation (CRWMS M&O 2000z), the near-field environment (NFE) as defined by its thermal hydrology and coupled processes (CRWMS M&O 2000y), and the unsaturated zone (CRWMS M&O 2000bb). It should be noted that in a few cases such a FEP has been designated as “excluded” from the TSPA relative to the EBS. It is important to note, however, that such a designation of “exclude” for the EBS does not mean that the FEP is necessarily “excluded” relative to another process modeling group.

1.3 FEPs SCREENING AND ANALYSIS PROCESS

As described in Section 1.2, the first step in the scenario development process was the identification and analysis of FEPs. The second step in the scenario development process includes the screening of each FEP. Each FEP is screened for inclusion or exclusion in the TSPA against three criteria, which are stated as regulatory requirements at NRC’s proposed rule 10 CFR Part 63 (64 FR 8640), and in the U.S. Environmental Protection Agency's (EPA) proposed rule 40 CFR Part 197 (64 FR 46976). The screening criteria are discussed in more detail in Section 4.2 and are summarized here.

- Is the FEP specifically ruled out by the guidance or proposed regulations, or contrary to the stated guidance or regulatory assumptions?

- Does the FEP have a probability of occurrence less than 10^{-4} in 10^{4} years?

- Will the resulting expected annual dose be “significantly changed” or the results of the performance assessment be “changed significantly” by omission of the FEP? (Note: “significantly changed” and “changed significantly” are undefined terms in the DOE Interim Guidance and in the EPA’s proposed regulations. These terms are inferred to be equivalent to having no or negligible effect.)

The regulatory screening criteria contained in DOE’s interim guidance (Dyer 1999) and in the proposed 40 CFR Part 197 (64 FR 46976) are relevant to many of the FEPs. FEPs that are contrary to DOE’s interim guidance, or specific proposed regulations, regulatory assumptions, or regulatory intent are excluded from further consideration. Examples include: the explicit exclusion of consideration of all but a stylized scenario to address treatment of human intrusion (10 CFR §63.113(d)), assumptions about the critical group to be considered in the dose assessment (10 CFR §63.115), and the intent that the consideration of "the human intruders" be excluded from the human intrusion assessment (64 FR 8640, Section XI. Human Intrusion).

Probability estimates used in the FEPs screening process may be based on technical analysis of the past frequency of similar events (such as igneous and seismic events) or, in some cases, on expert elicitation. Probability arguments, in general, require including some information about the magnitude of the event in its definition. Probability arguments are also sensitive to the spatial and temporal scales at which FEPs are defined. For example, the definition of the probability of a seismic event depends on the magnitude of the event. Probability arguments are therefore made at reasonably coarse scales.

Consequence-based screening arguments can be established in a variety of ways. Various methods include TSPA sensitivity analyses, modeling studies outside of the TSPA, or reasoned arguments based on literature research. For example, consequences of many geomorphic processes such as erosion and sedimentation can be evaluated by considering bounding rates reported in geologic literature. More complicated processes, such as igneous activity, require detailed analyses conducted specifically for the Yucca Mountain Project. Low-consequence arguments are often made by demonstrating that a particular FEP has no effect on the distribution of an intermediate performance measure in the TSPA. For example, by demonstrating that including a particular WF has no effect on the concentrations of radionuclides transported from the repository in the aqueous phase, it is also demonstrated that including this waste form in the inventory would not compromise compliance with the performance objectives. Explicit modeling of the characteristics of this waste form could therefore be excluded from the TSPA.

Using the type of arguments discussed above, each FEP identified as relevant to the EBS was reviewed against the three exclusion criteria. Those that were determined to meet one of the three criteria were designated as “excluded” from further consideration within the TSPA. Those that did not meet one of these criteria must, by definition, be “included.”

1.4 ORGANIZATION OF FEP DATABASE

Under a separate scope, the TSPA team is constructing an electronic database to assist project reviewers during the license review process. Each FEP has been entered as a separate record in the database. Fields within each record provide a unique identification number, a description of the FEP, the origin of the FEP, identification as a Primary or Secondary FEP for the purposes of the TSPA, and mapping to related FEPs and to the assigned PMRs. Fields also provide summaries of the screening arguments with references to supporting documentation and AMRs, and, for all retained FEPs, statements of the disposition of the FEP within the TSPA modeling system. The AMRs, however, contain the detailed arguments and description of the disposition of the subject FEPs.

Alphanumeric identifiers (called the “NEA category”) previously used have been retained in the database for traceability purposes. Each FEP has also been assigned a unique YMP FEP database number, based on the NEA categories. The database number is the primary method for identifying FEPs, and consists of an eight-digit number of the form x.y.zz.pp.qq. The general structure of the database is reflected in the first two digits (x.y) as shown below:

0.0. Assessment Basis

1.0. External Factors
- 1.1 Repository Issues
- 1.2 Geological Processes and Effects

1.3 Climatic Processes and Effects
1.4 Future Human Actions (Active)
1.5 Other

2.0. Disposal System - Environmental Factors
2.1 Wastes and Engineered Features
2.2 Geologic Environment
2.3 Surface Environment
2.4 Human Behavior

3.0. Disposal System - Radionuclide/Contaminant Factors
3.1 Contaminant Characteristics
3.2 Contaminant Release/Migration Factors
3.3 Exposure Factors

The next four digits (zz.pp) define a grouping structure for the FEPs, with zz designating the category, and pp designating the heading. The exact details of this grouping structure are not important to the evaluation, since each FEP will be evaluated regardless of the database organization. Finally, the last two digits (qq) signify whether the FEP is primary (00) or Secondary (other than 00). Each heading has a Primary FEP associated with it, and may or not have any Secondary FEPs. In those cases where Secondary FEPs do exist, the Primary FEP encompasses all the issues associated with the Secondary FEPs. The Secondary FEPs either provide additional detail concerning the primary, or are a restatement of the primary based on redundant input from a different source.

2. QUALITY ASSURANCE

The activities documented in this AMR were evaluated in accordance with QAP-2-0, *Conduct of Activities* and were determined to be quality affecting and subject to the requirements of the U.S. DOE Office of Civilian Radioactive Waste Management (OCRWM) *Quality Assurance Requirements and Description* (QARD) (DOE 2000). This evaluation is documented in *Conduct of Performance Assessment* (CRWMS M&O 1999e). Accordingly, the modeling or analysis activities documented in this AMR have been conducted in accordance with the Civilian Radioactive Waste Management System Management and Operating Contractor (CRWMS M&O) quality assurance program, using approved procedures identified in *Development Plan: EBS FEPs/Degradation Modes Abstraction* (CRWMS M&O 1999a).

More specifically, this AMR has been developed in accordance with procedure AP-3.10Q, *Analyses and Models*. Preparation of this analysis did not require the classification of items in accordance with QAP-2-3, *Classification of Permanent Items.* This activity is not a field activity. Therefore, an evaluation in accordance with NLP-2-0, *Determination of Importance Evaluations* was not required.

The list of the 84 FEPs addressed in this AMR was derived from the *YMP FEP Database Rev. 00c* (CRWMS M&O 1999c). Rev 00 of the FEPs database is currently scheduled as a Level 3 Milestone, as part of the Total System Performance Assessment - Site Recommendation (TSPA-SR) deliverables and will be maintained in accordance with YAP-SV.1Q Rev. 0, ICN1, *Control of the Electronic Management of Data*.

3. COMPUTER SOFTWARE AND MODEL USAGE

This AMR uses no computational software or model. The AMR was developed using only commercially available software (Microsoft Word 97) for word processing, which is exempt from qualification requirements in accordance with AP-SI.1Q, *Software Management*. There were no additional applications (routines or macros) developed using this commercial software. The analyses and arguments presented herein are based on regulatory requirements, results of analyses presented and documented in other AMRs, or technical literature.

4. INPUTS

4.1 DATA AND PARAMETERS

The nature of the FEPs screening arguments and TSPA dispositions is such that cited data and values form the basis of reasoned argument, as opposed to inputs to computational analyses or models. The data cited in the FEPs screening arguments is largely non-critical, and conclusions will be formulated such that they will not be affected by the degrees of uncertainty accounted for in the TSPA.

In addition to the above input, the potential repository baseline design (CRWMS M&O 1999f) was used as the reference design for the purpose of FEP identification and analysis. This design does consider the use of backfill material within the EBS.

4.2 CRITERIA

This AMR complies with the DOE interim guidance (Dyer 1999). Subparts of the interim guidance that apply to this analysis or modeling activity are those pertaining to the characterization of the Yucca Mountain site (Dyer 1999, Subpart B, Section 15). In particular, relevant parts of the guidance include the compilation of information regarding geology, hydrology, and geochemistry of the site (Dyer 1999, Subpart B, Section 21(c)(1)(ii)), and the definition of geologic, hydrologic, and geochemical parameters and conceptual models used in performance assessment (Dyer 1999, Subpart E, Section 114(a)).

Technical screening criteria are provided in DOE's interim guidance (Dyer 1999) and have also been identified by the NRC in the proposed 10 CFR Part 63 (64 FR 8640) and by the EPA in the proposed 40 CFR Part 197 (64 FR 46976). Both proposed regulations specifically allow the exclusion of FEPs from the TSPA if they are of low probability (less than one chance in 10,000 of occurring in 10,000 years) or if occurrence of the FEP can be shown to have no significant effect on expected annual dose. There is no quantified definition of "significant effect" in the guidance or proposed regulations.

4.2.1 Low Probability

The probability criterion is explicitly stated by the NRC in the proposed 10 CFR §63.114 (d):

> Consider only events that have at least one chance in 10,000 of occurring over 10,000 years.

The EPA provides essentially the same criterion in 40 CFR §197.40:

> The DOE's performance assessments should not include consideration of processes or events that are estimated to have less than one chance in 10,000 of occurring within 10,000 years of disposal.

4.2.2 Low Consequence

Criteria for low consequence screening arguments are provided in DOE's interim guidance (Dyer 1999, Section 114(e) and (f)), which indicates that performance assessment shall:

> (e) Provide the technical basis for either inclusion or exclusion of specific features, events, and processes of the geologic setting in the performance assessment. Specific features, events, and processes of the geologic setting must be evaluated in detail if the magnitude and time of the resulting expected annual dose would be significantly changed by their omission.
>
> (f) Provide the technical basis for either inclusion or exclusion of degradation, deterioration, or alteration processes of engineered barriers in the performance assessment, including those processes that would adversely affect the performance of natural barriers. Degradation, deterioration, or alteration processes of engineered barriers must be evaluated in detail if the magnitude and time of the resulting expected annual dose would be significantly changed by their omission.

The EPA provides essentially the same criteria in 40 CFR §197.40:

> …with the NRC's approval, the DOE's performance assessment need not evaluate, in detail, the impacts resulting from any processes and events or sequences of processes and

> events with a higher chance of occurrence if the results of the performance assessment would not be changed significantly.

The terms "significantly changed" and "changed significantly" are undefined terms in the DOE interim guidance and in the EPA's proposed regulations. These terms are inferred for FEPs screening purposes to be equivalent to having no or negligible effect. Because the relevant performance measures differ for different FEPs (e.g., effects on performance can be measured in terms of changes in concentrations, flow rates, travel times, and other measures, as well as overall expected annual dose), there is no single quantitative test of "significance."

4.2.3 Reference Biosphere

Both DOE's interim guidance (Dyer 1999) and EPA's proposed regulations specify assumptions (which in effect serve as criteria) pertinent to screening many of the EBS FEPs. Particularly germane are explicit assumptions regarding the reference biosphere (10 CFR §63.115), and less so are assumptions regarding the location and use of groundwater by the critical group used for calculation of exposure doses.

The assumptions pertaining to the characteristics of the reference biosphere are presented in DOE's interim guidance (Dyer 1999, Section 115(a)(1,4)). The specified characteristics pertinent to the EBS FEPs are that:

(1) Features, events, and processes …shall be consistent with present knowledge of the conditions in the region surrounding the Yucca Mountain site.

(4) Evolution of the geologic setting shall be consistent with present knowledge of natural processes.

The EPA has specified a similar assumption in proposed 40 CFR §197.15. This assumption is stated as:

> … DOE must vary factors related to the geology, hydrology, and climate based on environmentally protective but reasonable scientific predictions of the changes that could affect the Yucca Mountain disposal system over the next 10,000 years.

4.3 CODES AND STANDARDS

There are no Codes or Standards directly applicable to this analysis.

5. ASSUMPTIONS

5.1 GENERAL ASSUMPTIONS

There are two general assumptions used in the screening of the EBS FEPs.

5.1.1 Future Geologic Setting

As directed by DOE's interim guidance (Dyer 1999, Section 114(1)), the TSPA assumes that future geologic settings will be within the range of conditions that are consistent with present knowledge of natural processes.

This assumption is particularly germane to EBS FEPs, since the FEPs are screened based on known processes or phenomena that could potentially affect future states of the system. Discernible impacts from past events on the geologic setting are inherently reflected in the present knowledge of natural processes that form the basis of the TSPA. If the subject FEP phenomena do not have a documented past occurrence within the geologic time scale of concern and/or within the study area, or if past events are of an insignificant consequence, then it is by definition a low probability or low consequence event and can be excluded from consideration.

5.1.2 Repository Closure

The TSPA is based on an assumption that the repository will be constructed, operated, and closed according to regulatory requirements during the construction period.

This assumption is particularly germane to FEPs involving off-normal events during the construction phase of the repository or deviations from the as-designed repository configuration. By definition, such events and/or design deviations will not be explicitly considered in the TSPA.

These two assumptions are justified based on the conditions specified in DOE's interim guidance (Dyer 1999), which require special and periodic reporting of (1) progress of construction, (2) data not within predicted limits on which the facility design is based, and (3) any deficiency, that if uncorrected, could adversely affect safety. Additionally, restrictions on subsequent changes to the features or procedures will be a condition of construction authorization. Furthermore, the existing regulations specified in 10 CFR 63 Subpart F (Dyer 1999) require that a performance confirmation program be instituted. The focus of the program is to confirm the geotechnical design parameters and to ensure that appropriate action is taken to inform the NRC of changes needed to accommodate actual field conditions. It also includes provisions for design testing and monitoring of testing of waste packages to verify in-situ performance of the waste package design. The requirement is for these activities to be conducted in a manner that does not adversely affect the ability of the geologic and engineered elements of the geologic repository to meet the performance objectives. Additionally, all of these activities are subject to the quality assurance requirements specified in 10 CFR 63 Subpart G (Dyer 1999). Regardless of this assumption, the TSPA includes the possibility that engineered systems may not perform optimally for the full 10,000 years. For example, the premature failure of some waste packages is included in the TSPA through the probabilistic treatment of waste package degradation.

5.2 FEP-SPECIFIC ASSUMPTIONS

This section lists the EBS-specific assumptions used in Section 6. All of the assumptions were used as reference or logical analysis assumptions to facilitate the identification and analysis of FEPs and degradation scenarios. None of the assumptions are a requirement that need to be substantiated and, hence, none carries a TBV. It is particularly noted that, conceptually, all of the events and processes identified are potential scenarios, and as such, are assumed to occur for the purpose of analysis. It is also noted that the potential repository baseline design (CRWMS M&O 1999f) is used as a point of departure for FEP identification, but the latter is not restricted by the configuration or design requirements specified in that baseline. Examples of FEPs that go "beyond" the baseline are the development of gaps between drip shield segments due to a seismic event.

5.2.1 Engineered Barrier System Description

The EBS is assumed to extend as far into the rock as the reach of the ground support system (approximately 5 m if rock bolts are used). Thus, chemical processes involving such rock bolts and the surrounding cement are considered, as is degradation of the drift wall in this region. However, the determination of seepage flow into the tunnel, including the impact of geophysical changes in this region of the rock, is an NFE issue and is not considered as part of this EBS discussion. All flow into the tunnel is assumed to be provided as a boundary condition by the NFE analysis.

5.2.2 Reference Repository Design

The Enhanced Design Alternative II, as described in the baseline design (CRWMS M&O 1999f), is used as the reference design for FEP identification. Additional information is provided in the *License Application Design Selection Report* (LADS) (CRWMS M&O 1999b), as well as earlier documentation on subsurface facilities (CRWMS M&O 2000gg) and ground control systems (CRWMS M&O 2000hh). Key features of this design include the waste package sitting atop a pedestal and invert, a drip shield to minimize water contact with the waste packages, and backfill to protect the drip shield from rock fall. An extended period of preclosure ventilation ensures that maximum waste package temperatures are kept below allowable limits. However, departures from the baseline due to the potential occurrence of FEPs are also addressed.

5.2.3 Degradation

Evolution of the repository over time is assumed to never result in improvements in performance.

- As the potential repository and Yucca Mountain evolve, the properties of EBS components such as ground support, backfill, and drip shield, which are subjected to “processes,” depart from their original design characteristics. By assumption, it is presumed that any such departure degrades the function of the component, and design lifetimes and safety factors are selected on the basis of that premise.

- The design philosophy currently assumes no credit for favorable alterations to the repository system (e.g., encasement of WPs in calcium carbonate precipitated from incoming water).

5.2.4 Degradation During Preclosure Period

Degradation that occurs during the preclosure period would be detected and “fixed.” Thus, the FEPs identified are mostly those that occur during the postclosure period.

5.2.5 Process Starting Point

The starting point of most EBS processes is assumed to be the entry of water into the emplacement drift. It is with the introduction of water that key degradation processes such as corrosion start to occur. However, there are certain processes that are independent of water ingress that must also be considered. These include, for example, rock fall and the deposition of dust on the waste packages and drip shields during the preclosure period. Rock fall may occur at any time and could represent a mechanism for drip shield damage. Dust deposited on the drip shields and waste packages would serve as loci for surface wetting when the relative humidity increases, but prior to liquid water entry.

All data associated with water entry into the emplacement drift, including timing, rate, temperature, chemistry, etc., are assumed to be developed in the unsaturated zone and near field environment PMRs.

6. ANALYSIS/MODEL

The method used for this analysis is a combination of qualitative and quantitative screening of FEPs. The analyses are based on the criteria provided in the DOE’s interim guidance (Dyer 1999) and by the EPA in the proposed 40 CFR Part 197 (64 FR 46976). These criteria are used to determine whether each FEP should be included in the TSPA.

For FEPs that are excluded based on specific regulatory requirements (e.g., requirements regarding the location and composition of the critical group), the screening argument includes the regulatory reference and a short discussion of the applicability of the standard.

For FEPs that are excluded from the TSPA based on DOE's interim guidance or EPA criteria, the screening argument includes the basis of the exclusion (low probability, low consequence) and provides a short summary of the screening argument. As appropriate, screening arguments cite work done outside this activity, such as in other AMRs.

For FEPs that are included in the TSPA, the TSPA Disposition includes a reference to the AMR that describes how the FEP has been incorporated in the process models or the TSPA abstraction.

6.1 ALTERNATIVE APPROACHES

To ensure clear documentation of the treatment of potentially relevant future states of the system in the Yucca Mountain License Application, the DOE has chosen to adopt a scenario development process based on the methodology developed by Cranwell et al. (1990) for the NRC. The approach is fundamentally the same as that used in many performance assessments. The approach has also been used by the DOE for the Waste Isolation Pilot Plant (WIPP) (DOE 1996), by the NEA, and by other radioactive waste programs internationally (e.g., Skagius and Wingefors 1992). Regardless of the "scenario" method chosen for the performance assessment, the initial steps in the process involve development of a FEPs list and screening of the FEPs list for inclusion or exclusion.

The approach used to identify, analyze, and screen the FEPs (as described in Sections 1.2 and 1.3) was also considered. Alternative classification of FEPs as Primary or Secondary is possible in an almost infinite range of combinations. Classification into Primary and Secondary FEPs is based primarily on redundancy and on subject matter. Subsequent assignment and analysis by knowledgeable subject matter experts for evaluation appeared to be the most efficient methodology for ensuring a comprehensive assessment of FEPs as they relate to the TSPA. Alternative classifications and assignments of the FEPs are entirely possible, but would still be based on subjective judgement. Alternative approaches for determining probabilities and consequences used as a basis for screening are discussed in Section 6.2 under the individual FEP analysis.

In practice, regulatory-type criteria were examined first, and then either probabilities or consequences were examined. FEPs that are retained on one criterion are also considered against the others. Consequently, the application of the analyst's judgement regarding the order in which to apply the criteria does not affect the final decision. Allowing the analyst to choose the most appropriate order to apply the criteria prevents needless work, such as developing quantitative probability arguments for low consequence events or complex consequence models for low probability events. For example, there is no need to develop detailed models of the response of the repository to faults shearing a WP, if it can be shown that this event has a probability below the criteria threshold.

Regardless of the specific approach chosen to perform the screening, the screening process is in essence a comparison of the FEP against the criteria specified in Section 4.2. Consequently, the outcome of the screening is independent of the particular methodology or assignments selected to perform the screening.

Alternative interpretations of data as they pertain directly to the FEPs screening are provided in the Analysis and Discussion section for each FEP, as discussed below. The FEPs screening decisions may also rely on the results of analyses performed and documented as separate activities. Alternate approaches related to separate activities and analyses are addressed in the AMRs for those analyses and are not discussed in this AMR.

6.2 EBS FEPs EVALUATION AND ANALYSIS

This AMR addresses the 84 Primary FEPs that have been identified as EBS FEPs in the FEPs database (CRWMS M&O 1999c), as well as the 37 EBS FEPs identified internal to the project by the EBSO. Because the internally identified FEPs were developed independently, there is considerable overlap between the two sets of FEPs. Many of the EBSO developed FEPs are a restatement of ones that are already in the database. Thus they can be considered to be secondary FEPs that do not need to be explicitly discussed herein. Table 3 lists the 37 FEPs developed by the EBSO along with a reference to the associated FEPs database primary FEP. In those cases where an appropriate existing primary FEP does not exist, the EBSO FEP is designated as "new primary".

Table 3. Relationship of EBSO FEPs to Database FEPs

FEP ebs #	FEP Name	Corresponding Primary Database FEP
1	Pedestal Collapse	2.1.06.05.00 – Degradation of Invert and Pedestal
2	Drip Shield	2.1.06.06.00 – Effects and Degradation of Drip Shield
3	Drip Shield Supports	2.1.07.03.00 – Movement of Containers (a)
4	Backfill	2.1.04.0x.00 – Five Backfill FEPs (b)
5	Invert	2.1.06.05.00 – Degradation of Invert and Pedestal
6	Rockfall Loading Distortion of Drip Shield	2.1.07.01.00 - Rockfall
7	Rails	2.1.09.02.00 – Interaction with Corrosion Products
8	Pedestal	2.1.06.05.00 – Degradation of Invert and Pedestal
9	Ground Motion	2.1.06.05.00 – Degradation of Invert and Pedestal (c) 2.1.06.06.00 – Effects and Degradation of Drip Shield 2.1.06.07.00 – Effects at Material Interfaces 2.1.07.01.00 – Rockfall 2.1.07.02.00 – Mechanical Degradation or Collapse of Drift
10	Drip Shield Movement Relative to Waste Packages/Rails	2.1.06.06.00 – Effects and Degradation of the Drip Shield
11	Relative Seismic Displacement	2.1.06.05.00 – Degradation of Invert and Pedestal (c) 2.1.06.06.00 – Effects and Degradation of Drip Shield 2.1.06.07.00 – Effects at Material Interfaces 2.1.07.01.00 – Rockfall 2.1.07.02.00 – Mechanical Degradation or Collapse of Drift
12	Ground Support Failure	2.1.06.02.00 – Effects of Rock Reinforcement Materials
13	Thermo-Mechanical Evolution of a	2.1.08.08.00 – Induced Hydrological Changes in the Waste and EBS (d)

Table 3. Relationship of EBSO FEPs to Database FEPs - Continued

FEP ebs #	FEP Name	Corresponding Primary Database FEP
	Repository Block	
14	Shear Fracture/ Fault Movement and Relaxation	2.1.08.08.00 – Induced Hydrological Changes in the Waste and EBS (d) (also see ebs #11)
15	Condensation Beneath Drip Shield	2.1.06.06.00 – Effects and Degradation of Drip Shield
16	Reflux Drainage of Condensate Zone	2.2.07.06.00 – Episodic / Pulse Release from Repository
17	Flow along Drip Shield (inside) Wall	2.1.06.06.00 – Effects and Degradation of Drip Shield
18	Flow Through Backfill	2.1.04.01.00 – Preferential Pathways in the Backfill
19	Movement of Backfill Through Gaps and Separations in Drip Shield	2.1.06.06.00 – Effects and Degradation of Drip Shield
20	Fluid Flow into Gaps and Separations in Drip Shield	2.1.06.06.00 – Effects and Degradation of Drip Shield
21	Ground Support – Wire Mesh and Rockbolts	2.1.06.02.00 – Effects of Rock Reinforcement Materials
22	Ground Support – Rockbolts and Grout	2.1.06.01.00 – Degradation of Cementitious Materials in Drift 2.1.06.02.00 – Effects of Rock Reinforcement Materials
23	Drains (if used)	New primary
24	Flow Along Drip Shield (outside) Wall	2.1.06.06.00 – Effects and Degradation of Drip Shield
25	Microbial Activity	2.1.10.01.00 – Biological Activity in Waste and EBS
26	Rockbolt/Grout Corrosion	2.1.06.01.00 – Degradation of Cementitious Materials in Drift (d) 2.1.06.02.00 – Effects of Rock Reinforcement Materials
27	Drainage with Transport – Sealing and Plugging	New Primary (d)
28	Drainage – Through Constructed Drains	See ebs # 23
29	Drainage with Transport – Ponding	See ebs # 27
30	Drip Shield Corrosion – Flow of Backfill Through Corroded Elements	2.1.06.06.00 – Effects and Degradation of Drip Shield
31	Drip Shield Corrosion – Fluid Flow Through Corroded Elements to Waste Packages	2.1.06.06.00 – Effects and Degradation of Drip Shield
32	Corrosion of Drip Shields and Waste Packages	2.1.06.06.00 – Effects and Degradation of Drip Shield
33	Local, disruptive ground motion is produced by an earthquake occurring outside the potential repository	See database FEP 1.2.01.01.00 – Tectonic Activity – large scale, FEP 1.2.02.01.00 – Fractures, and FEP 1.2.03.01.00 – Seismicity for discussion of integrated effects (e). Specific effects within EBS are covered by FEPs above.
34	Faulting or movement on an existing fault occurs through the potential repository	See database FEP 1.2.01.01.00 – Tectonic Activity – large scale, FEP 1.2.02.01.00 – Fractures, and FEP 1.2.03.01.00 – Seismicity for discussion of integrated effects (e). Specific effects within EBS are covered by FEPs above.
35	Thermo- chemical alteration of glasses to clays and zeolites, in this unit beneath the potential repository, accompanied by volume increases which appear at the nearest free surface, namely the drift floors.	2.1.07.06.00 – Floor buckling
36	A basaltic intrusion intersects potential repository drifts and may reach the surface. EBS design and performance is of little significance for this occurrence.	1.2.04.03.00 – Igneous Intrusion

Table 3. Relationship of EBSO FEPs to Database FEPs - Continued

FEP ebs #	FEP Name	Corresponding Primary Database FEP
37	Stress alteration, increase, and relaxation during repository life causes massive failure of ground support, initiating a sequence of associated failures	2.1.07.02.00 – Mechanical Degradation or Collapse of Drift

(a) – actual WP corrosion due to drip shield contact with waste package is a WP issue
(b) – 5 primary FEPs are included in the database dealing with backfill
(c) – each of these FEPs is impacted by seismic events
(d) – effects occurring in the rock outside of the drift are considered in the NFE analysis and would be accounted for in the EBS analysis via inlet flow boundary conditions
(e) – these FEPs are not EBS specific and are not discussed herein

Each of the 84 primary FEPs from the database and 2 new primary FEPs taken from the EBSO list is discussed in the sections that follow. For the primary FEPs, the section title for each discussion provides the FEP name as incorporated in the FEPs database (CRWMS M&O 1999c), as well as the Yucca Mountain FEP number that has been assigned. The FEP description is also taken directly from the database, with the exception that in several cases additional text has been added to reference applicable Secondary FEPs relevant to the EBS discussion. For the additional new primary FEPs, a similar format is used.

The ongoing modeling and analysis of the EBS is documented in numerous AMRs. These AMRs represent the principal references for the discussion on how each FEP is dealt with in the TSPA. A list of the AMRs is provided in Table 4 below. In the following discussion on the EBS FEPs, the AMR ID number (rather than the document ID number) will be used to reference the relevant EBS AMR for that discussion. It should be noted that the key AMRs that define most of the direct feeds to the TSPA are E0010, *Physical and Chemical Environment Abstraction Model* (CRWMS M&O 2000b); E0095, *EBS Radionuclide Transport Abstraction* (CRWMS M&O 2000q); and E0080, *Drift Degradation Analysis* (CRWMS M&O 2000n). For the most part, the other AMRs provide supporting modeling detail that support these abstractions, but do not feed the TSPA directly. Hence they will typically not be referenced directly in the discussion.

Also provided in each FEP section is a cross reference to key technical issues identified by the NRC (NRC 1998 a-b, NRC 1999a-f, Reamer 1999) as being important for the Yucca Mountain repository. These are identified as Issue Resolution Status Report (IRSR) issues. The key technical issues and subissues are listed below. The relevance of these subissues to the EBS FEPs is identified in Sections 6.2.1 through 6.2.84. Whenever the key technical issue (CLST, for example) is identified rather than a specific subissue, all subissues apply.

Table 4. Engineered Barrier System Relevant Analysis Model Report Identification

AMR Title	AMR ID	Reference	Document ID Number
Invert Diffusion Properties Model	E0000	CRWMS M&O 2000a	ANL-EBS-MD-000031
Physical and Chemical Environment Abstraction Model	E0010	CRWMS M&O 2000b	ANL-EBS-MD-000046

AMR Title	AMR ID	Reference	Document ID Number
Engineered Barrier System Features, Events, and Processes/Degradation Modes Analysis	E0015	CRWMS M&O 2000c	ANL-EBS-MD-000035
In Drift Corrosion Products	E0020	CRWMS M&O 1999d	ANL-EBS-MD-000041
Seepage/Backfill Interactions	E0030	CRWMS M&O 2000d	ANL-EBS-MD-000039
In-Drift Gas Flux & Composition	E0035	CRWMS M&O 2000e	ANL-EBS-MD-000040
In-Drift Microbial Communities	E0040	CRWMS M&O 2000f	ANL-EBS-MD-000038
In-Drift Colloids and Concentrations	E0045	CRWMS M&O 2000g	ANL-EBS-MD-000042
EBS Radionuclide Transport Model	E0050	CRWMS M&O 2000h	ANL-EBS-MD-000034
Seepage/Cement Interactions	E0055	CRWMS M&O 2000i	ANL-EBS-MD-000043
Seepage/Invert Interactions	E0060	CRWMS M&O 2000j	ANL-EBS-MD-000044
In-Drift Thermal-Hydrological-Chemical Model	E0065	CRWMS M&O 2000k	ANL-EBS-MD-000026
Water Drainage Model	E0070	CRWMS M&O 2000l	ANL-EBS-MD-000029
Ventilation Model	E0075	CRWMS M&O 2000m	ANL-EBS-MD-000030
Drift Degradation Analysis	E0080	CRWMS M&O 2000n	ANL-EBS-MD-000027
Water Diversion Model	E0085	CRWMS M&O 2000o	ANL-EBS-MD-000028
Water Distribution and Removal Model	E0090	CRWMS M&O 2000p	ANL-EBS-MD-000032
EBS Radionuclide Transport Abstraction	E0095	CRWMS M&O 2000q	ANL-WIS-PA-000001
Physical and Chemical Environment Model	E0100	CRWMS M&O 2000r	ANL-EBS-MD-000033
In-Drift Precipitates/Salts Analysis	E0105	CRWMS M&O 2000s	ANL-EBS-MD-000045
Multiscale Thermohydrologic Model	E0120	CRWMS M&O 2000t	ANL-EBS-MD-000049
Abstraction of Near Field Environment Drift Thermodynamic Environment and Percolation Flux	E0130	CRWMS M&O 2000u	ANL-EBS-HS-000003
In-Package Chemistry Abstraction for TSPA-LA	F0170	CRWMS M&O 2000w	ANL-EBS-MD-000037

Container Life and Source Term (CLST)

CLST1 The effects of corrosion processes on the lifetime of the containers

CLST2 The effects of phase stability of materials and initial defects on the mechanical failure and lifetime of the containers

CLST3 The rate at which radionuclides in spent nuclear fuel (SNF) are released from the EBS through the oxidation and dissolution of spent fuel

CLST4 The rate at which radionuclides in high-level break (HLW) glass are leached and released from the EBS

CLST5 The effect of in-package criticality on WP and EBS performance

CLST6 The effect of alternate EBS design features on container lifetime and radionuclide release from the EBS

Evolution of the Near-Field Environment (ENFE)

ENFE1 Effects of coupled thermal-hydrologic-chemical processes on seepage and flow

ENFE2 Waste package chemical environment

ENFE3 Chemical environment for radionuclide release

ENFE4 Effects of thermal-hydrological-chemical (THC) processes on radionuclide transport through engineered and natural barriers

ENFE5 Coupled THC processes affecting potential nuclear criticality in the near field

Igneous Activity (IA)

IA1 Probability of future IA

IA2 Consequences of IA within the repository setting

Radionuclide Transport (RT)

RT1 Physical and chemical system affecting RT

RT2 RT through fractured rock

RT3 RT through porous rock

RT4 RT through alluvium

Repository Design and Thermal-Mechanical Effects (RDTME)

RDTME1 Design control processes

RDTME2 Seismic design methodology

RDTME3 Thermal-mechanical effects on underground facility design and performance

RDTME4 Design and long-term contribution of seals to performance

Structural Deformation and Seismicity (SDS)

SDS1 Fault slip

SDS2 Seismic motion

SDS3 Fractures and site discontinuities

SDS4 Tectonics and crustal conditions

Thermal Effects on Flow (TEF)

TEF1 Sufficiency of thermal-hydrologic testing program to assess thermal flux

TEF2 Sufficiency of thermal-hydrologic modeling to predict the nature and bounds of thermal effects on flow in the near field

TEF3 Adequacy of total system performance assessment with respect to thermal effects on flow

Total System Performance Assessment and Integration (TSPAI)

TSPAI1 Demonstration of the overall performance objective

TSPAI2 Demonstration of multiple barriers

TSPAI3 Model abstraction

TSPAI4 Scenario analysis

TSPAI5 Transparency and traceability of the analysis

Unsaturated and Saturated Flow under Isothermal Conditions (USFIC)

USFIC1 Range of future climates

USFIC2 Hydrologic effects of climate change

USFIC3 Amount and spatial distribution of present-day shallow groundwater infiltration

USFIC4 Amount and spatial distribution of groundwater percolation through repository horizon (present-day, and through period of repository performance)

USFIC5 Ambient flow conditions in the saturated zone and likely dilution mechanisms

USFIC6 Extent of matrix diffusion in unsaturated and saturated zones

6.2.1 Excavation/Construction – YMP 1.1.02.00.00

FEP Description: This FEP is concerned with the effects associated with excavation/construction of the underground regions of the repository on the long-term behavior of the engineered and natural barriers. Excavation-related effects include changes to rock properties due to boring and blasting and chemical changes to the rock and incoming groundwater due to potential explosives residue. Excavation and other construction activities could also directly cause groundwater chemistry changes within the tunnel due to the impact of such contaminants as diesel exhaust, explosives residues, or other organic contaminants (Secondary FEP 1.1.02.00.03). Finally, oxidizing water introduced into the repository during excavation/construction could impact repository conditions/performance (Secondary FEP 1.1.02.00.04).

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Excavation-related effects may impact both the natural and engineered barriers in the repository. The impact on the natural barrier (i.e., rock surrounding the tunnel) may be both mechanical and chemical. The mechanical effects from construction could impact the calculation of drift degradation/rock fall. However, this is explicitly accounted for in the rock properties used for these degradation analyses (see E0080 - *Drift Degradation Analysis* (CRWMS M&O 2000n)), and thus no further analysis is required.

Any chemical effects on rock properties and/or the properties of incoming water due to residues deposited within the rock matrix fall within the scope of the NFE analysis and are not an issue relative to the EBS analysis. To the extent that incoming water properties are initially impacted by excavation-related effects, this would be provided to the EBS analysis from the NFE analysis via appropriate boundary conditions.

Additional changes to the groundwater chemistry could occur as a result of materials left/deposited within the tunnel (diesel exhaust, explosives residues, residual organic contaminants, etc.). A detailed assessment of such groundwater chemistry changes can be found in CRWMS M&O 1995b. This document determines acceptable upper bounds on materials introduced into the repository prior to closure such that the impact of these materials has negligible consequences on repository performance. It is assumed that these limits will be adhered to during the preclosure phase of operation.

Because the emplacement drifts are situated in the unsaturated zone of the repository, any water entering the drifts will be oxidizing throughout the entire history of the repository. Thus, there are no effects associated with influx of oxidizing water during construction/excavation that are not already modeled implicitly in the TSPA.

TSPA Disposition This FEP is excluded from the TSPA (for the EBS) on the basis of low consequences.

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0080 (CRWMS M&O 2000n)

6.2.2 Site Flooding (During Construction and Operation) – YMP 1.1.02.01.00

FEP Description: Flooding of the site during construction and operation could introduce water into the underground tunnels, which could affect the long-term performance of the repository. (Note that this is a specific example of an accident or unplanned event discussed under FEP 1.1.12.01.00.)

Screening Decision: Exclude

Screening Decision Basis: Regulatory (see Section 5.1.2 for discussion)

Screening Argument: The possibility of flooding was considered in the location of the entry ramps and surface buildings. As a result of this, the current design makes flooding of the underground areas, which would require redirection of runoff (e.g., down ramps), highly unlikely. In general, operational issues are outside the scope of the TSPA. Operation will be according to procedures acceptable to the NRC and EPA. Quality control procedures are designed to detect operational events resulting in deviations from the repository design that might affect long-term performance. Any deviation would be detected during regulator audits and inspections and be corrected before further work in the repository would be allowed to continue. Examples of accidents and unplanned events include: repository flooding, sabotage, handling damage to waste containers, leaks of undesirable materials, and explosions.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of regulatory considerations (outside the scope of the TSPA objectives).

IRSR Issues: None

References: Dyer 1999, 64 FR 8640, 64 FR 46976

6.2.3 Effects of Preclosure Ventilation – YMP 1.1.02.02.00

FEP Description The duration of preclosure ventilation acts together with waste package spacing (as per design) to control the extent of the boiling front within the NFE.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: The early thermal history of the repository (and associated water inflow) are strongly influenced by preclosure ventilation, and these in turn have a significant impact on EBS component performance. Thus, these are important issues relative to EBS performance. However, this is primarily accounted for via the NFE boundary conditions (water influx and temperature) provided to the EBS analysis, and thus is not strictly speaking an EBS analysis issue.

TSPA Disposition: The effects of preclosure ventilation are considered in the EBS analysis via suitable boundary conditions (temperature, flow) from the NFE analysis.

IRSR Issues: TEF1, TEF2, TEF3

References: E0095 (CRWMS M&O 2000q), E0010 (CRWMS M&O 2000b), E0105 (CRWMS M&O 2000s)

6.2.4 Undesirable Materials Left – YMP 1.1.02.03.00

FEP Description: During construction and preclosure operation of the repository there might be possibilities for leaving unwanted material in the vicinity of the radioactive waste. These materials could be of different kinds and could to some extent affect many long-term processes in the repository from canister corrosion to transport mechanisms of radionuclides. (Note that this FEP has some overlap with the issues discussed under FEP 1.1.02.00.00.)

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Materials introduced during the preclosure construction and operation phase of the repository may, if not controlled, have a conceivably unconstrained impact on groundwater chemistry within the EBS, thereby impacting corrosion processes, radionuclide transport, etc. A detailed assessment of such groundwater chemistry changes can be found in CRWMS M&O 1995b. This document determines acceptable upper bounds on materials introduced into the repository prior to closure such that the impact of these materials has negligible consequences on repository performance. It is assumed that these limits will be adhered to during the preclosure phase of operation.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b)

6.2.5 Error in Waste or Backfill Emplacement – YMP 1.1.03.01.00

FEP Description: Deviations from the design and/or errors in waste and backfill emplacement could affect long-term performance of the repository. A specific example of such an error that has been raised involves erroneously emplacing the waste packages in the saturated zone of the repository (Secondary FEP 1.1.03.01.04). This would clearly impact the repository performance both by impacting container corrosion and failure as well as by impacting radionuclide transport.

Screening Decision: Exclude

Screening Decision Basis: Regulatory (see Section 5.1.2 for discussion)

Screening Argument: Waste and backfill will be emplaced according to repository design. Alternative emplacement designs, with and without backfill have been considered, but the TSPA assumes a single emplacement strategy. Within this single emplacement strategy, the impact of uncertainties in such parameters as environmental conditions and the impact of allowable tolerances in design parameters is explicitly accounted for in the TSPA. Deviations beyond those considered are excluded on the basis of the repository quality control program. In general, the TSPA is based on an assumption that the repository will be constructed, operated, and closed according to design. Deviations from design during the operational period are the subject of an extensive quality control program, and are outside the scope of the long-term performance assessment. Significant deviations that are detected during the operational period will be corrected. Residual uncertainty remaining after implementation of quality control has been included in the TSPA in the performance of some design features (allowing, for example, for the possibility of juvenile failure of some waste packages).

The specific example of waste package emplacement within the wet zone of the repository is most relevant to a particular design option - vertical, in-floor borehole emplacement - that is no longer considered. The current design involves horizontal, in-drift emplacement of very large containers (to 100 tonnes). Wet zones are readily detectable and thus can be avoided.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of regulatory considerations (beyond the scope of the TSPA objectives).

IRSR Issues: CLST1, CLST2, ENFE1, ENFE4, TEF1, TEF2, TEF3

References: Dyer 1999, 64 FR 8640, 64 FR 46976

6.2.6 Repository Design – YMP 1.1.07.00.00

FEP Description: This category contains FEPs related to the design of the repository, and the ways in which the design contributes to long-term performance. Changes to or deviations from the specified design may affect the long-term performance of the disposal system.

Screening Decision: Include (exclude deviations from design)

Screening Decision Basis: N/A

Screening Argument: All aspects of the repository design are accounted for in the TSPA. Individual elements of this design (drip shield, pedestal, invert, ground support, etc.) are covered by other EBS FEPs. In general, the TSPA is based on an assumption that the repository will be constructed, operated, and closed according to design. Deviations from design during the operational period are the subject of an extensive quality control program, and are outside the scope of the long-term performance assessment. If the repository does not meet regulatory criteria, it will not be licensed and waste will not be emplaced. Significant deviations that are detected during the operational period will be corrected, and therefore, are excluded from the TSPA on the basis of regulatory considerations.

TSPA Disposition: The TSPA is based on an assumption that the repository will be constructed, operated, and closed according to design. Modifications and/or deviations from the design are excluded on the basis of regulatory requirements (deliberate design changes) and low probability (significant effects from undetected deviations).

IRSR Issues: All

References: Dyer 1999, 64 FR 8640, 64 FR 46976

6.2.7 Quality Control – YMP 1.1.08.00.00

FEP Description: This category contains FEPs related to quality assurance and control procedures and tests during the design, construction, and operation of the repository, as well as the manufacture of the waste forms, containers, and engineered features. Lack of quality control could result in material defects, faulty waste package fabrication, and faulty or non-design-standard construction, all of which may lead to reduced effectiveness of the engineered barriers.

Screening Decision: Include (exclude defects and deviations)

Screening Decision Basis: N/A

Screening Argument: In general, the TSPA is based on an assumption that the repository will be constructed, operated, and closed according to design. Deviations from design during the operational period are the subject of an extensive quality control program, and are outside the scope of the long-term performance assessment. If the repository does not meet regulatory criteria, it will not be licensed and waste will not be emplaced. Significant deviations that are detected during the operational period will be corrected, and therefore, are excluded from the TSPA on the basis of low probability.

Residual uncertainty remaining after implementation of quality control has been included in the TSPA in the performance analysis of some design features (allowing, for example, for the possibility of juvenile failure of some waste packages).

TSPA Disposition: The TSPA is based on an assumption that the repository will be constructed, operated, and closed according to design under an acceptable quality control plan. Deviations from the design due to poor quality control are excluded on the basis of regulatory requirements (deliberate design changes) and low probability (significant effects from undetected deviations). Material defects are included only in juvenile failures of containers.

IRSR Issues: All

References: Dyer 1999, 64 FR 8640, 64 FR 46976

6.2.8 Accidents and Unplanned Events During Operation – YMP 1.1.12.01.00

FEP Description: The long-term performance of the disposal system might be seriously affected by unplanned or improper activities that take place during construction, operation, and closure of the repository.

Screening Decision: Exclude

Screening Decision Basis: Regulatory (see Section 5.1.2 for discussion)

Screening Argument: In general, operational issues are outside the scope of the TSPA. Operation will be according to procedures acceptable to the NRC and EPA. Quality control procedures are designed to detect operational events resulting in deviations from the repository design that might affect long-term performance. Any deviation would be detected during regulator audits and inspections and would be corrected before further work in the repository would be allowed to continue. Examples of accidents and unplanned events include: repository flooding, sabotage, handling damage to waste containers, leaks of undesirable materials, and explosions.

For the purposes of the TSPA, the effects of these types of events are assumed to be corrected before closure. Therefore, accidents and unplanned events during the operational phase that could have a significant effect on long-term performance and that remain undetected at the time of closure are excluded from the TSPA on the basis of regulatory considerations.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of regulatory considerations (outside the scope of the TSPA objectives).

IRSR Issues: None

References: Dyer 1999, 64 FR 8640, 64 FR 46976

6.2.9 Retrievability – YMP 1.1.13.00.00

FEP Description: This category contains FEPs related to design, emplacement, operational, or administrative measures that might be applied or considered in order to enable or ease retrieval of wastes. There may be a requirement to retrieve all or part of the waste stored in the repository (e.g., to recover valuable fissile materials or to replace defective containers).

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: This FEP is explicitly considered in the design requirements for the repository. Regulation requires that the repository be designed in such a way that removing the waste is not precluded for a reasonable period of time after emplacement. Current DOE policy allows for the possibility of keeping the repository open at least 100 years after the initiation of emplacement, with a reasonable expectation that the repository could, with appropriate maintenance, be kept open for up to 300 years after the initiation of waste emplacement. Aspects of the repository design related to waste retrievability (such as the design of the drifts and emplacement of the waste packages) are included in the repository design that is used as the basis for the TSPA modeling.

TSPA Disposition: Retrievability is implicitly considered in all phases of the TSPA through the repository design parameters.

IRSR Issues: All

References: CRWMS M&O 1999f

6.2.10 Igneous Intrusion Into Repository – YMP 1.2.04.03.00

FEP Description: Magma from an igneous intrusion may flow into the drifts and extend over a portion of the repository site, forming a sill. The sill could be limited to the drifts or a continuous sill could form along the plane of the repository, bridging between adjacent drifts.

Note that this FEP also encompasses FEP ebs # 36 from table 3.

Screening Decision: Exclude (for EBS)

Screening Decision Basis: N/A for EBS

Screening Argument: The impact of an igneous intrusion into the repository is significant in that it changes the fundamental response of the EBS. For this reason, this FEP is not considered as part of the EBS analyses, but rather is considered as part of a stand-alone tectonics analysis documented in CRWMS M&O 2000z.

TSPA Disposition: This FEP is not considered as part of the EBS analysis.

IRSR Issues: IA1, IA2

References: CRWMS M&O 2000z

6.2.11 Corrosion of Waste Containers – YMP 2.1.03.01.00

FEP Description: Corrosion may contribute to waste package failure. Corrosion is most likely to occur at locations where water drips on the waste packages, but other mechanisms should be considered.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: The time-dependent water distribution and the chemistry of this water relative to waste package corrosion are important parameters relative to repository performance. Special consideration of anoxic corrosion (FEP 2.1.03.01.04) can be excluded from the TSPA on the basis of low probability, because for a repository located in the unsaturated zone, the connection to the atmosphere ensures an oxidizing environment at all times.

TSPA Disposition: The TSPA corrosion model considers general corrosion, pitting, and stress corrosion cracking in both wet and dry environments for the drip shield and waste package materials. The treatment of these phenomena is part of the WP analysis effort, and a discussion of their treatment may be found in the FEPs summary discussion for WP documented in CRWMS M&O 2000dd. The EBS analysis provides two key sets of parameters to the WP analysis; the time-dependent rate of water contact with both drip shield and waste package (as described in E0095 (CRWMS M&O 2000q)), and the chemistry of this water (as described in E0010 (CRWMS M&O 2000b)).

IRSR Issues: CLST1, ENFE2

References: E0095 (CRWMS M&O 2000q), E0010 (CRWMS M&O 2000b), CRWMS M&O 2000dd

6.2.12 Container Healing – YMP 2.1.03.10.00

FEP Description: Pits and holes in waste packages could be partially or fully plugged by chemical or physical reactions during or after their formation, affecting corrosion processes and water flow and radionuclide transport through the breached container. Passivation by corrosion products is a potential mechanism for container healing.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Container healing is not considered by itself. Rather, container failure and breach (when liquids can leave a container) are described by a distribution function for analyses (CRWMS M&O 2000ff).

TSPA Disposition: For purposes of the EBS response analysis, the timing of waste package failure is provided by the results of the WP analysis (CRWMS M&O 2000cc), as input into the EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000q). While the potential for container healing is inherently a WP analysis issue (see WP FEPs discussion (CRWMS M&O 2000dd)), the EBS analysis does provide to the WP analysis the chemistry of the groundwater contacting both the drip shield and waste package. This is discussed in the EBS physical and chemical environmental abstraction, E0010 (CRWMS M&O 2000b).

IRSR Issues: CLST1, ENFE2, RT1

References: E0010 (CRWMS M&O 2000b), E0095 (CRWMS M&O 2000q), CRWMS M&O 2000cc, CRWMS M&O 2000dd

6.2.13 Container Failure (Long-term) – YMP 2.1.03.12.00

FEP Description Waste packages and drip shields have a potential to fail over long periods of time by a variety of mechanisms, including general corrosion, stress corrosion cracking, pit corrosion, hydride cracking, microbially-mediated corrosion, internal corrosion, and mechanical impacts.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Long-term failure of the WPs and drip shields must be accounted for in TSPA analyses as this defines the timing of radionuclide release and transport.

TSPA Disposition: WP and drip shield failure is calculated explicitly as part of the waste package analysis (CRWMS M&O 2000cc). A discussion of these issues relative to the WP analysis may be found in the WP FEPs (CRWMS M&O 2000dd). The EBS TSPA models provide critical inputs for that analysis including the timing of water contact as discussed in E0095 (CRWMS M&P 2000q), the chemistry of the water as discussed in E0010 (CRWMS M&O 2000b), and the timing and impact of rock-fall as discussed in E0080 (CRWMS M&O 2000n). Note that the properties of the failed containers relative to their impact on EBS performance are addressed as part of FEP 2.1.08.07.00, and the chemical buffering effects of the failed containers are addressed as part of FEP 2.1.09.02.00.

IRSR Issues: CLST1, CLST2

References: E0010 (CRWMS M&O 2000b), E0095 (CRWMS M&O 2000q), E0080 (CRWMS M&O 2000n), CRWMS M&O 2000cc, CRWMS M&O 2000dd

6.2.14 Preferential Pathways in the Backfill – YMP 2.1.04.01.00

FEP Description: Preferential pathways for flow and diffusion may exist within the backfill and may affect long-term performance of the waste packages. Backfill may not preclude hydrological, chemical, and thermal interactions between waste packages within a drift.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: The backfill represents a preferential pathway for seepage into the drift because it tends to funnel fluid into the emplacement drift due to its capillarity. This has an important impact on water contact with the drip shield and the resulting corrosion. In addition, the potentially high water content of the backfill impacts the in-drift thermal response due to waste package heat generation.

Note that this FEP also encompasses FEPs ebs # 5 and 18 from table 3.

TSPA Disposition: The effect of the backfill on water transport within the drift is accounted for in the EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000q). Most notably, this considers the capillary effects of the backfill as a mechanism for enhanced water transport to the drip shield. This analysis is in turn based on the calculated thermal/hydrological response of the drifts, as delineated in E0065 (CRWMS M&O 2000k). That analysis explicitly considers the effect of the backfill on the thermal response of the drift environment.

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0095 (CRWMS M&O 2000q), E0065 (CRWMS M&O 2000k)

6.2.15 Physical and Chemical Properties of Backfill – YMP 2.1.04.02.00

FEP Description: The physical and chemical properties of the backfill may affect groundwater flow, waste package and drip shield durability, and radionuclide transport in the waste disposal region.

Note that this FEP also encompasses FEP ebs # 5 from table 3.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: The properties of the backfill have a significant effect on the transport of water to the drip shield, and hence must be considered explicitly in the TSPA.

TSPA Disposition: The porosity and permeability of the quartz sand backfill (and crushed tuff in the invert) are represented in the thermal/hydrological response of the WPs and drip shields in the emplacement drifts as discussed in E0065 (CRWMS M&O 2000k). These calculations define the fluid flux due to capillarity, the temperature and relative humidity at the WP, and the potential for condensation on the underside of the drip shield due to evaporation from the invert. The effects of the chemical properties of the sand backfill and the crushed tuff on transport are ignored in the TSPA analyses because of two conservative assumptions: (1) there is no sorption in the invert and in the sand backfill, and (2) chemical changes to the backfill seem likely to divert seepage away from the WP (CRWMS M&O 2000q). The chemical properties of the backfill are, however, considered in the analysis of seepage/backfill chemical interactions as discussed in E0030 (CRWMS M&O 2000d) and E0010 (CRWMS M&O 2000b).

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), E0030 (CRWMS M&O 2000d), E0065 (CRWMS M&O 2000k), E0095 (CRWMS M&O 2000q)

6.2.16 Erosion or Dissolution of Backfill – YMP 2.1.04.03.00

FEP Description: Solid material in buffer or backfill is carried away by flowing groundwater, either by erosion of particulate matter or by dissolution.

Note that this FEP also encompasses FEP ebs # 5 from table 3.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Backfill material at Yucca Mountain is quartz sand, and thus will not be highly soluble and no significant loss due to dissolution is anticipated. Furthermore, flow rates in the unsaturated environment of the repository will be too low to cause significant erosion. Any limited erosion that does occur would be expected to have negligible impact on repository performance. Wicking of water to the drip shield surface would be unimpacted by a slight reduction in backfill volume. Further, the degree of backfill erosion would not be expected to be significant enough to reduce drip shield protection from rock fall.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0030 (CRWMS M&O 2000d)

6.2.17 Mechanical Effects of Backfill – YMP 2.1.04.04.00

FEP Description: Backfill may alter the mechanical evolution of the drift environment by providing resistance to rock creep and rock fall, by changing the thermal properties of the drift, or by other means. Impacts of the evolution of the properties of the backfill itself should be considered.

Note that this FEP also encompasses FEP ebs # 5 from table 3.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Backfill is a key component of the EBS and as such must be explicitly accounted for in the TSPA.

TSPA Disposition: The presence of the backfill is explicitly included in estimating the mechanical response of the drip shield to rockfall by distributing the load from a rockfall over a larger area of the drip shield. It is also included in evaluating the waste package environment because the backfill is assumed to fall through any penetrations through the drip shield and form a continuous fluid path between the backfill and the waste package as discussed in E0095 (CRWMS M&O 2000q). Finally, in addition to the direct impacts delineated above, the backfill also influences the thermal response of the repository (CRWMS M&O 2000k), which in turn can influence the character of rock fall.

IRSR Issues: CLST2, CLST6

References: E0095 (CRWMS M&O 2000q), E0065 (CRWMS M&O 2000k), E0080 (CRWMS M&O 2000n)

6.2.18 Backfill Evolution - YMP 2.1.04.05.00

FEP Description: Properties of the backfill may change through time, due to processes such as silica cementation, alteration of minerals, thermal effects, and physical compaction. These changes could then affect the movement of water and radionuclides in the backfill.

Note that this FEP also encompasses FEP ebs # 5 from table 3.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: The evolution of backfill properties must be considered. However, as discussed below, the neglect of such changes in the current TSPA is conservative relative to water transport to the waste packages and thus radionuclide transport to the unsaturated zone (UZ).

TSPA Disposition: Backfill affects the performance of the drip shields and WPs in two ways: It acts to mitigate the impact of rock fall, and it serves to create a uniform water distribution via wicking of water through this material. While localized welding of the backfill material would not be expected for the temperatures in the EBS, even if such localized agglomeration did occur, it would have an insignificant impact on repository performance. Mitigation of rockfall impacts would still occur. In addition, such localized welding could only serve to reduce the rate of water transport to the drip shield surface. Thus, excluding such an effect would be conservative. The same argument holds for the formation of a low permeability rind on the top of the backfill. Such a rind will tend to divert seepage from the drip shield and WP, and thus it is conservative to neglect this effect. Thus, the physical properties (porosity, permeability) of the backfill are assumed to remain constant over time in the EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000q). Detailed chemical studies are evaluating the geochemical environment during the first few thousand years, when the backfill will be very hot and evaporation will generate strong ionic solutions and precipitated salts in the backfill or on the drip shield. The chemical processes in the backfill are currently qualitatively assessed in the seepage/backfill interaction analysis, E0030 (CRWMS M&O 2000d) in support of E0010 (CRWMS M&O 2000b).

IRSR Issues: CLST2, ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), E0030 (CRWMS M&O 2000d), E0095 (CRWMS M&O 2000q)

6.2.19 Properties of Bentonite – YMP 2.1.04.06.00

FEP Description: This category contains FEPs specific to the properties of bentonite buffers. Because the Yucca Mountain design does not include bentonite backfill, all FEPs in this category are irrelevant to the YMP TSPA.

Screening Decision: Exclude

Screening Decision Basis: Low (Zero) Probability

Screening Argument: No use of bentonite is planned for Yucca Mountain, thus the probability for this FEP is by definition zero.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not relevant to YMP design).

IRSR Issues: None

References: CRWMS M&O 1999f

6.2.20 Buffer Characteristics – YMP 2.1.04.07.00

FEP Description: This category contains FEPs specific to repository designs that include chemical buffering agents in the waste disposal region. The Yucca Mountain design does not include buffering agents, and all FEPs in this category are irrelevant to the YMP TSPA.

Screening Decision: Exclude

Screening Decision Basis: Low (Zero) Probability

Screening Argument: There is no buffer used in the current design at Yucca Mountain, thus the probability associated with this FEP is by definition zero.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not relevant to YMP design).

IRSR Issues: None

References: CRWMS M&O 1999f

6.2.21 Diffusion in Backfill – YMP 2.1.04.08.00

FEP Description: Diffusion processes in backfill may affect waste package performance and radionuclide transport.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Diffusion in backfill is excluded from the TSPA on the basis of low consequence. The quartz sand backfill is upstream of the waste package from a flow viewpoint. In this situation, radionuclides can only reach the backfill when the downward advective flux through the drip shield is negligible and when there is a continuous fluid pathway that allows upward diffusion across the gap between drip shield and waste package. When the drip shield is intact there is no flow path. When the drip shield has been breached there will be a flow path (through backfill sitting on the waste package); however, upward diffusion will be negligible in comparison to downward advection (see E0095 (CRWMS M&O 2000q)). Diffusion through the backfill is therefore screened out for the TSPA analyses.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: ENFE1, RT1

References: E0095 (CRWMS M&O 2000q)

6.2.22 Radionuclide Transport Through Backfill – YMP 2.1.04.09.00

FEP Description: Radionuclide transport in the drift environment may be affected by the presence of backfill. Transport of both dissolved and colloidal species, advective and diffusive effects and sorption processes should be considered.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Radionuclide transport in backfill is excluded from the TSPA on the basis of low consequence. The quartz sand backfill is upstream of the waste package from a flow viewpoint. In this situation, radionuclides can only reach the backfill when the downward advective flux through the drip shield is negligible and when there is a continuous fluid pathway that allows upward diffusion across the gap between drip shield and waste package. When the drip shield is intact there is no flow path. When the drip shield has been breached there will be a flow path (through backfill sitting on the waste package); however, upward diffusion will be negligible in comparison to downward advection and transport (see E0095 (CRWMS M&O 2000q)). Radionuclide transport through the backfill is therefore screened out for the TSPA analyses.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: ENFE1, ENFE4, RT1

References: E0095 (CRWMS M&O 2000q)

6.2.23 Degradation of Cementitious Materials in Drift – YMP 2.1.06.01.00

FEP Description: Degradation of cementitious material used for any purposes in the disposal region may affect long-term performance through both chemical and physical processes. Degradation may occur by physical, chemical, and microbial processes.

Note that this FEP also encompasses FEPs ebs # 22 and 26 from table 3.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Degradation of cementitious materials has an impact on water chemistry, and thus must be considered in the TSPA.

TSPA Disposition: The effects of the degradation of cementitious material in the drift-stabilization structures are analyzed in the cement seepage interactions analysis, E0055 (CRWMS M&O 2000i), supporting E0010 (CRWMS M&O 2000b). The specific chemical concerns associated with cementitious materials are further discussed in FEP 2.1.09.01.00.

IRSR Issues: CLST1, ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), E0055 (CRWMS M&O 2000i)

6.2.24 Effects of Rock Reinforcement Materials – YMP 2.1.06.02.00

FEP Description: Degradation of rock bolts, wire mesh, and other materials used in ground control may affect the long-term performance of the repository.

Note that this FEP also encompasses FEPs ebs # 12, 21, 22, and 26 from table 3.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Degradation of ground control materials has two potentially important effects on repository performance that must be considered in the TSPA; the impact on drift stability/degradation and the impact on water chemistry due to evolved corrosion products.

TSPA Disposition: The effect of ground control devices (rock bolts and wire mesh) and their associated degradation is considered explicitly in the drift degradation analysis, E0080 (CRWMS M&O 2000n). The effects of the corrosion products due to the degradation of metal reinforcing components in the drift-stabilization structures are analyzed in the corrosion products analysis, E0020 (CRWMS M&O 1999d), supporting E0010 (CRWMS M&O 2000b).

IRSR Issues: CLST1, CLST2, ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), E0020 (CRWMS M&O 1999d), E0080 (CRWMS M&O 2000n)

6.2.25 Degradation of the Liner – YMP 2.1.06.03.00

FEP Description Degradation of materials used to line the drifts may occur by physical, chemical, or microbial processes, and may affect long-term performance.

Screening Decision: Exclude

Screening Decision Basis: Low (Zero) Probability

Screening Argument: No liner is planned for the repository (other than the steel mesh for ground support) (CRWMS M&O 1999f). Thus, this FEP is not relevant to the YMP design, and the probability is by definition zero.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not relevant to YMP design).

IRSR Issues: None

References: CRWMS M&O 1999f

6.2.26 Flow Through the Liner – YMP 2.1.06.04.00

FEP Description: Groundwater flow may occur through the liner.

Screening Decision: Exclude

Screening Decision Basis: Low (Zero) Probability

Screening Argument: No liner is planned for the repository (other than the steel mesh for ground support) (CRWMS M&O 1999f). Thus, this FEP is not relevant to the YMP design, and the associated probability is by definition zero.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not relevant to YMP design).

IRSR Issues: None

References: CRWMS M&O 1999f

6.2.27 Degradation of Invert and Pedestal – YMP 2.1.06.05.00

FEP Description: Degradation of the materials used in the invert and the pedestal supporting the waste package may occur by physical, chemical, or microbial processes, and may affect the long-term performance of the repository.

Note that this FEP also encompasses FEPs ebs # 1, 5, 8, 9, and 11 from table 3.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Physical degradation of the invert and invert materials has been screened out of the TSPA on low consequence. The invert is a minor barrier to flow in comparison to the drip shield, waste package, and unsaturated zone beneath the drift. Minor changes in the physical properties of the invert will have negligible impact on system performance. As such, the invert is assumed to provide no resistance to flow in the EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000q).

Physical degradation of the pedestal is an important process because (1) the waste package will be in direct contact with the invert after the pedestal collapses, and (2) the waste package may roll off a degraded invert and impact the drip shield during a seismic event.

TSPA Disposition: To account for potential pedestal failure, the radionuclide transport abstraction for the EBS, E0095 (CRWMS M&O 2000q) conservatively assumes that the waste package is in direct contact with the invert at all times. The TSPA model for drip shield separation demonstrates that the impact from pedestal failure and contact between waste package and drip shield is incorporated in the large uncertainty in the seismic displacement model for the drip shield. The effects of pedestal degradation products on seepage water chemistry are analyzed explicitly in the TSPA as discussed in the *In Drift Corrosion Products* AMR, E0020 (CRWMS M&O 1999d), supporting E0010 (CRWMS M&O 2000b).

IRSR Issues: CLST2, ENFE1, RT1, RDTME1, RDTME2, RDTME3

References: E0010 (CRWMS M&O 2000b), E0020 (CRWMS M&O 1999d), E0095 (CRWMS M&O 2000q)

6.2.28 Effects and Degradation of Drip Shield – YMP 2.1.06.06.00

FEP Description: The drip shield will affect the amount of water reaching the waste package. Behavior of the drip shield in response to rockfall, ground motion, and physical, chemical degradation processes should be considered. Effects of the drip shield on the disposal region environment (for example, changes in relative humidity and temperature below the shield) should be considered for both intact and degraded conditions. Degradation processes specific to the chosen material should be identified and considered. For example, oxygen embrittlement should be considered for titanium drip shields.

Note that this FEP also encompasses FEPs ebs # 2, 9, 10, 11, 15, 17, 19, 20, 24, 30, 31, and 32 from table 3.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: The drip shield is an important element of the EBS, and as such its as-designed function and degradation must be explicitly considered in the TSPA. Certain aspects of this functionality (degradation of the drip shield due to chemical processes) are considered directly in the WP analysis (see WP FEPs summary (CRWMS M&O 2000dd). However, the remaining aspects of drip shield behavior are considered as part of the EBS analysis.

TSPA Disposition: The EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000q) explicitly considers the impact of the drip shield on flow. Prior to drip shield failure, no direct pathway for water flow from the backfill to the waste package exists. However, the potential for condensation of water on the underside of the drip shield and the subsequent dripping of this condensate on the waste packages is considered. Failure of the drip shield is provided via the WP analysis outputs (CRWMS M&O 2000cc) for chemically-induced failures or is explicitly considered as part of the EBS analysis for drift shield separation due to seismic events (CRWMS M&O 2000q). Subsequent to the calculation of such failures, fluid can reach the waste packages directly. For chemically-induced failures (corrosion), the EBS analysis provides directly the chemical environment on these structural surfaces (CRWMS M&O 2000ee), which has a key influence on the rate of such corrosion. The effects of the corrosion products associated with drip shield degradation on seepage water chemistry are analyzed as part of the *In Drift Corrosion Products* AMR, E0020 (CRWMS M&O 1999d), supporting E0010 — (CRWMS M&O 2000b).

IRSR Issues: CLST1, CLST2, ENFE2, RT1, SDS

References: E0010 (CRWMS M&O 2000b), E0020 (CRWMS M&O 1999d), E0095 (CRWMS M&O 2000q), CRWMS M&O 2000cc, CRWMS M&O 2000dd, CRWMS M&O 2000ee

6.2.29 Effects at Material Interfaces – YMP 2.1.06.07.00

FEP Description: Physical and chemical effects that occur at the interfaces between materials in the drift, such as at the contact between the backfill and the drip shield, may affect the performance of the system.

Note that this FEP also encompasses FEPs ebs # 9 and 11 from table 3.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: The basic chemical processes that occur at phase boundaries (principally liquid/solid) are included in the geochemical modeling supporting E0010 (CRWMS M&O 2000b) and its associated submodel AMRs. Solid/solid contact either does occur or could occur between the drip shield and the invert and/or backfill, between the waste package and the invert and/or backfill; between the pedestal and the waste package and/or drip shield; and between the waste form and any of the other EBS component materials. Since these materials are all relatively inert, no solid/solid interaction mechanisms have been identified that are significant relative to the basic seepage water induced corrosion of the EBS components.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: RT1

References: E0010 (CRWMS M&O 2000b), E0095 (CRWMS M&O 2000q)

6.2.30 Rockfall (Large Block) – YMP 2.1.07.01.00

FEP Description: Rockfalls may occur that are large enough to mechanically tear or rupture waste packages.

Note that this FEP also encompasses FEPs ebs # 6, 9, and 11 from table 3.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Large-block rockfall is a possibility in the drifts. Such blocks could be loosed during the thermal period when thermal expansion causes considerable compressive forces and reorientation of the least principal stress. However, such rockfall is excluded from the TSPA based on low consequences. An analysis of the possible formation of key blocks within the repository horizon has been provided in the *Drift Degradation Analysis* AMR, E0080 (CRWMS M&O 2000n). Block failure due to seismic and thermal effects has also been analyzed. Analysis activities involve using analytical methods, including the Universal Distinct Element Code (UDEC) and the Discrete Region Key Block Analysis (DRKBA) numerical code, and performing calculations and statistical analyses to determine the expected quantities, locations, size distributions, and frequencies of rock fall, for the repository emplacement drifts. The results indicate that seismic, time-dependent, and thermal effects have a relatively minor impact on rock fall.

The LADS (CRWMS M&O 1999b) for the repository is Enhanced Design Alternative II, which includes a drip shield and backfill as barriers. The presence of these design features precludes rock fall as a credible scenario contributing to waste package failure. Since the thermal and seismic impacts on rock fall are minimal, rock fall is excluded from the TSPA based on low probability that a rock fall event could penetrate the designed engineered barriers and impact a waste package.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: CLST2, RDTME, SDS

References: E0080 (CRWMS M&O 2000n), CRWMS M&O 1999b

6.2.31 Mechanical Degradation or Collapse of Drift – YMP 2.1.07.02.00

FEP Description: Partial or complete collapse of the drifts, as opposed to discrete rockfall, could occur as a result of seismic activity, thermal effects, stresses related to excavation, or possibly other mechanisms. Drift collapse could affect stability of the engineered barriers and waste packages. Drift collapse may be localized as stopping at faults or other geologic features. Rockfall of small blocks may produce rubble throughout part or all of the tunnel.

Note that this FEP also encompasses FEPs ebs # 9, 11, and 37 from table 3.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Changing stress state, either from fault (tectonic) adjustment or from seismic waves arriving from distal sources, produces rockfall and liner failure. Such displacement of surrounding rocks into the tunnels and attendant growth of the tunnel (possibly by chimneying) is categorized as tunnel failure. A distinction is made between the thermal and post-thermal states because the thermally induced compression around the drifts is expected to require higher ground accelerations in order to induce tunnel failure than for the post-thermal relaxing environment. However, such mechanical degradation or collapse of the drift is excluded from the TSPA based on low consequences. It is unlikely that drift degradation could penetrate the designed engineered barriers and impact a waste package. The LADS (CRWMS M&O 1999b) for the repository is Enhanced Design Alternative II, which, in addition to the waste package itself, includes a drip shield and backfill as barriers. The presence of these design features precludes drift degradation as a credible scenario contributing to waste package failure. A detailed analysis of drift degradation is provided in E0080 (CRWMS M&O 2000n).

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: CLST2, RDTME, SDS

References: E0080 (CRWMS M&O 2000n), CRWMS M&O 1999b

6.2.32 Movement of Containers – YMP 2.1.07.03.00

FEP Description: Waste packages may move as a result of seismic activity, degradation of the invert or pedestal, rockfall, fault displacement, or other processes (See also FEP 2.1.06.05.00 - Degradation of Invert and Pedestal.)

Note that this FEP also encompasses FEP ebs # 3 from table 3.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Movement of the waste packages is potentially important because it can result in direct contact between the waste package and the invert (and thus, to additional contact with water if the invert is wet). In addition, movement of the waste packages against the drip shield can result in drip shield separation.

TSPA Disposition: The mechanisms of rockfall, floor heave, and thermal expansion have been screened out of the TSPA as causing drip shield separation because of low consequence (see E0095 (CRWMS M&O 2000q)). The mechanism of seismic response has been retained in the TSPA through the drip shield separation model. The mechanism of pedestal failure has also been retained because it is assumed to be included in the bounding model for seismic response. The radionuclide transport abstraction for the EBS (as documented in E0095 (CRWMS M&O 2000q)) conservatively ignores the pedestal and assumes that the waste package is in direct contact with the invert at all times. Thus, any accelerated corrosion due to the presence of saturated water in the invert would be automatically accounted for.

The abstraction for drip shield separation (as documented in E0095 (CRWMS M&O 2000q)) screens out container movement against the drip shield as a significant contributor to drip shield separation. It is argued therein that the consequences of contact between waste package and drip shield from pedestal failure are accounted for in the large uncertainty that is considered in the seismic displacement model for the drip shield.

IRSR Issues: CLST1, CLST2, RDTME, SDS

References: E0095 (CRWMS M&O 2000q)

6.2.33 Hydrostatic Pressure on Container – YMP 2.1.07.04.00

FEP Description: Waste packages emplaced in the saturated zone will be subjected to hydrostatic pressure in addition to stresses associated with the evolution of the waste and barrier system.

Screening Decision: Exclude

Screening Decision Basis: Low (Zero) Probability

Screening Argument: A repository at Yucca Mountain locates waste above the water table in a fractured, porous medium. Thus, the pressure is approximately atmospheric. Consequently, this FEP is not relevant for the YMP design, which calls for emplacement in the unsaturated zone, and the probability is by definition zero.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not relevant to YMP design).

IRSR Issues: CLST2

References: None

6.2.34 Creeping of Metallic Materials in the EBS – YMP 2.1.07.05.00

FEP Description: Metals used in the waste package or drip shield may deform by creep processes in response to deviatoric stress.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: The size of the containers is such that creep, as a response to pressurization or external damage or manufacturing stress, is a second order process compared to corrosion and is simply subsumed in its description. Temperatures in the drift will not exceed creep temperature of 350 degrees C (CRWMS M&O 2000k). Any potential uncertainty associated with this phenomenon is covered by the uncertainty analysis done for the WP and drip shield failure analysis (CRWMS M&O 2000ff).

TSPA Disposition: This FEP is excluded from the TSPA on the basis of negligible consequences.

IRSR Issues: CLST2

References: CRWMS M&O 2000ff, CRWMS M&O 2000k

6.2.35 Floor Buckling – YMP 2.1.07.06.00

FEP Description: Buckling, or heave, of the drift floor occurs in response to changing stress. Floor buckling may affect the performance of components of the EBS such as the drip shield, the invert, and the pedestal. Effects may include movement of EBS components, and changes in the topography of the surface of the drift floor and invert that may affect water flow.

Note that this FEP also encompasses FEP ebs # 35 from table 3.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: The effect of floor heave and buckling on drip shield response has been screened out of the TSPA because of low consequence. Calculations documented in E0095 (CRWMS M&O 2000q) demonstrated that the vertical displacement of the floor due to in situ stress and thermal response will be on the order of 10 mm. This displacement will produce only minor shifting in the drip shields and will not compromise their integrity because the overlap between adjacent drip shields is much larger, between 200 mm and 600 mm. The effect of floor heave on position of the waste packages is also minor. A displacement of 10 millimeters at one end of a 5000 millimeter long package results in an angle of inclination of less than one degree. The impacts of floor heave and buckling have therefore been screened out of the TSPA.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of negligible consequences.

IRSR Issues: RDTME3

References: E0095 (CRWMS M&O 2000q)

6.2.36 Increased Unsaturated Water Flux at the Repository – YMP 2.1.08.01.00

FEP Description: An increase in the unsaturated water flux at the repository affects thermal, hydrological, chemical, and mechanical behavior of the system. Extremely rapid influx could reduce temperatures below the boiling point during part or all of the thermal period. Increases in flux could result from climate change, but the cause of the increase is not an essential part of the FEP.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Climate is expected to change. As a surrogate for that change, three climate states with different infiltration fluxes have been considered in TSPA modeling

TSPA Disposition: This is implicitly included in the EBS modeling through the water influx time histories as provided from the NFE analysis (CRWMS M&O 2000aa).

IRSR Issues: None for EBS

References: CRWMS M&O 2000aa

6.2.37 Enhanced Influx (Philip's drip) – YMP 2.1.08.02.00

FEP Description: An opening in unsaturated rock alters the hydraulic potential, affecting local saturation around the opening and redirecting flow. Some of the flow is directed to the opening where it is available to seep into the opening.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Philip's drip is a consequence of a drift of a certain dimension and shape intercepting a homogeneous, isotropic phreatic zone in such a way that it produces saturated conditions at the crown of the drift. This type of flow is esoteric, has been derived analytically, but is not currently supported experimentally. It is also not expected to compete in volume with drip from infiltrate or condensate (Philip et al. 1989).

TSPA Disposition: This FEP is excluded from the TSPA on the basis of negligible consequences.

IRSR Issues: None for EBS

References: (Philip et al. 1989)

6.2.38 Condensation Forms on Backs of Drifts – YMP 2.1.08.04.00

FEP Description: Emplacement of waste in drifts creates a large thermal gradient across the drifts. Moisture condenses on the roof and flows downward through the backfill.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: All potential pathways for water to reach the waste package must be considered to predict the onset of waste package failure.

TSPA Disposition: The possibility of condensation forming on the backs of drifts is included in the thermal/hydraulical calculations of emplacement drift response, as documented in E0065 (CRWMS M&O 2000k). The possibility of condensation forming on the underside of the drip shield due to evaporation from the invert is also calculated and included in the EBS model for the TSPA (E0065 (CRWMS M&O 2000k)). Both of these water seepage mechanisms are incorporated in the EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000q).

IRSR Issues: CLST1, ENFE, RT1, TEF

References: E0095 (CRWMS M&O 2000q), E0065 (CRWMS M&O 2000k)

6.2.39 Flow Through Invert – YMP 2.1.08.05.00

FEP Description: The invert, a porous material consisting of crushed tuff, separates the waste package from the bottom of the tunnel (boundary to the UZ).

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Flow of seepage water and associated radionuclides, as applicable, through the invert must be modeled to characterize the source term for the UZ.

TSPA Disposition: Advective and diffusive flow through the invert are included in the EBS radionuclide transport abstraction for TSPA, E0095 (CRWMS M&O 2000q). No credit for radionuclide transport delay mechanisms (for example, sorption) is included; a conservative modeling simplification.

IRSR Issues: ENFE1, ENFE4

References: E0095 (CRWMS M&O 2000q)

6.2.40 Wicking in Waste and EBS – YMP 2.1.08.06.00

FEP Description: Capillary rise, or wicking, is a potential mechanism for water to move through the waste and engineered barrier system.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: With the inclusion of a quartz sand backfill in the current repository design, wicking is an important water transport mechanism that must be accounted for.

TSPA Disposition: Wicking in the sand backfill and invert is included in the calculated thermal/hydraulical response of the emplacement drift and surrounding host rock as documented in E0065 (CRWMS M&O 2000k). This wicking flux is included in calculating the fluid influx into the EBS as documented in E0095 (CRWMS M&O 2000q).

IRSR Issues: ENFE1, ENFE2, ENFE4, RT1

References: E0095 (CRWMS M&O 2000q), E0065 (CRWMS M&O 2000k)

6.2.41 Pathways for Unsaturated Flow and Transport in the Waste and EBS – YMP 2.1.08.07.00

FEP Description: Unsaturated flow and radionuclide transport may occur along preferential pathways in the waste and EBS. Physical and chemical properties of the EBS and waste form, in both intact and degraded states, should be considered in evaluating pathways.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: The details of internal pathways providing release from a container are subsumed in an integrated release distribution.

TSPA Disposition: The EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000q) uses conservative assumptions to bound the impact of potential pathways on flow and transport. First, the waste form and waste package are represented as a single mixing cell. This mixing cell instantaneously equilibrates chemically with the waste form. In addition, there is no flow resistance into or out of the mixing cell. Second, pathways through the invert are ignored because the invert is a minor barrier to flow and transport in comparison to the waste package, the drip shield, or the UZ beneath the drift.

IRSR Issues: ENFE1, ENFE2, ENFE4, RT1

References: E0095 (CRWMS M&O 2000q)

6.2.42 Induced Hydrological Changes in the Waste and EBS – YMP 2.1.08.08.00

FEP Description: Thermal, chemical, and mechanical processes related to the construction of the repository and the emplacement of waste may induce changes in the hydrological behavior of the system.

Note that this FEP also encompasses FEPs ebs # 13 and 14 from table 3.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: The hydrological behavior of the repository is influenced by the presence of the emplacement drift and the associated waste material. This must be accounted for in the performance assessment of the repository.

TSPA Disposition: Relative to the EBS analysis, there are two ways in which induced hydrologic changes are accounted for. To the extent that the repository outside the tunnel is impacted (temperature, seepage flow, gas flow, etc.), this is accounted for in the EBS analysis through the boundary conditions provided by the NFE analysis and is not explicitly an EBS issue. Within the tunnel, the hydrological response of the EBS system is explicitly considered through the in-drift thermal-hydrological-chemical analysis, E0065 (CRWMS M&O 2000k), taking into account the emplacement of the waste packages. This analysis is then an integral part of the EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000q) that feeds the TSPA.

IRSR Issues: ENFE1, ENFE4, RDTME3, TEF

References: E0095 (CRWMS M&O 2000q), E0065 (CRWMS M&O 2000k)

6.2.43 Saturated Groundwater Flow in Waste and EBS – YMP 2.1.08.09.00

FEP Description: Saturated flow and radionuclide transport may occur along preferential pathways in the waste and EBS. Physical and chemical properties of the EBS and waste form, in both intact and degraded states, should be considered in evaluating pathways.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Saturated flow pathways in the waste are screened out because the failed canister is conservatively assumed to provide no resistance to flow. Saturated flow pathways in the quartz sand backfill are screened out because analyses (CRWMS M&O 2000k) have shown that wicking, driven by capillary forces, will distribute seepage uniformly throughout the drifts. Finally, saturated flow pathways in the invert are ignored because the invert is a very minor engineered barrier in the repository system, so that fast pathways in the invert will have negligible impact on performance.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: ENFE1, ENFE4

References: E0095 (CRWMS M&O 2000q), E0065 (CRWMS M&O 2000k)

6.2.44 Resaturation of Repository – YMP 2.1.08.11.00

FEP Description: Water content in the repository will increase following the peak thermal period.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: The time-dependent water content in the repository is a key parameter that affects corrosion processes as well as waste form degradation.

TSPA Disposition: The seepage influx and the capillary influx to the EBS are calculated as part of the NFE analysis as documented in E0065 (CRWMS M&O 2000k). This analysis calculates the coupled thermal/hydraulic response of the emplacement drifts and EBS and provides this as input to the EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000q).

IRSR Issues: None for EBS

References: E0095 (CRWMS M&O2000q), E0065 (CRWMS M&O 2000k)

6.2.45 Properties of the Potential Carrier Plume in the Waste and EBS – YMP 2.1.09.01.00

FEP Description: When unsaturated flow in the drifts is re-established following the peak thermal period, water will have chemical and physical characteristics influenced by the near field host rock and EBS. Water chemistry may be strongly affected by interactions with cementitious materials.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: When the flow system re-establishes itself through the repository, because of repository temperature and introduced materials (principally concrete and Fe) the flow system will include the characteristics of the repository (pH, temperature, dissolved constituents, etc.). Thus, for example, fluids entering the drift interact chemically with the cementitious reinforcement around the rock bolts, producing a hyperalkaline fluid. It is this hyperalkaline fluid which interacts with the waste container and its contents. The chemistry of this plume determines the solubility of contaminants and their behavior in transport. Such a hyperalkaline plume interacts rapidly with glassified waste, converting glasses to clays, and thus must be considered in the TSPA.

TSPA Disposition: The chemical and other properties of the carrier plume are assumed to be those of water in the invert where it is in contact with the UZ flow system. These properties are developed in the *Seepage/Invert Interactions* AMR, E0060 (CRWMS M&O 2000j**)**, supporting E0010 (CRWMS M&O 2000b**)**. These properties are influenced by the effects of the degradation of cementitious material in the drift-stabilization structures, which are analyzed in the *Seepage/Cement Interactions* AMR, E0055 (CRWMS M&O 2000i**)**, and the corrosion of EBS metallic components, which are analyzed in the *In Drift Corrosion Products* AMR, E0020 (CRWMS M&O 1999d).

IRSR Issues: ENFE2, ENFE3, RT1

References: E0095 (CRWMS M&O 2000q), E0010 (CRWMS M&O 2000b), E0020 (CRWMS M&O 1999d), E0060 (CRWMS M&O 2000j), E0055 (CRWMS M&O 2000i)

6.2.46 Interaction with Corrosion Products – YMP 2.1.09.02.00

FEP Description Corrosion products produced during degradation of the metallic portions of the EBS and waste package may affect the mobility of radionuclides. Sorption/desorption and coprecipitation/dissolution processes may occur.

Note that this FEP also encompasses FEP ebs # 7 from table 3.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Interaction of contaminants with corrosion products (from the breached waste package or its carcass, from the pedestal, from rock reinforcement materials, etc.) is expected to control mobilization and speciation of the contaminants (e.g., Fe oxyhydroxides and colloids) and thus must be included in the performance assessment.

TSPA Disposition: The effects of corrosion products on seepage water chemistry are analyzed in the *In Drift Corrosion Products* AMR, E0020 (CRWMS M&O 1999d) and the in-package chemistry abstraction documented in F0170 (CRWMS M&O 2000w**)** supporting E0010 (CRWMS M&O 2000b). (See also FEPS 2.1.06.02.00.) Flow interactions with these corrosion products have been screened out of the TSPA radionuclide transport abstraction, E0095 (CRWMS M&O 2000q). Corrosion products can potentially sorb radionuclides and provide resistance to flow through patches and pits. However, these features are conservatively ignored in the TSPA model.

IRSR Issues: ENFE3, RT1

References: E0095 (CRWMS M&O 2000q), E0010 (CRWMS M&O 2000b), E0020 (CRWMS M&O 1999d), F0170 (CRWMS M&O 2000w)

6.2.47 In-drift Sorption – YMP 2.1.09.05.00

FEP Description: Sorption of radionuclides within the waste and EBS may affect the aqueous concentrations.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Sorption of radionuclides on other materials within the EBS would serve to delay release to the environment. Thus, it is conservative from a consequences perspective to ignore this effect.

TSPA Disposition: As a bounding estimation, sorption of fission products within the EBS, which would act to delay release, is conservatively ignored.

IRSR Issues: RT1

References: E0095 (CRWMS M&O 2000q)

6.2.48 Reduction-oxidation Potential in Waste and EBS – YMP 2.1.09.06.00

FEP Description: The redox potential in the waste and EBS influences the oxidation of barrier and waste-form materials and the solubility of radionuclide species. Local variations in the redox potential can occur.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Redox potential in the waste and engineered barrier system is included in TSPA modeling of the waste form and waste package. Redox potential in the drift environment has been considered in analysis of the potential for criticality.

TSPA Disposition: Because of the location of the repository in the UZ, oxidizing conditions are assumed for all geochemical modeling supporting the TSPA.

IRSR Issues: RT1

References: E0010 (CRWMS M&O 2000b), E0035 (CRWMS M&O 2000e), F0170 (CRWMS M&O 2000w)

6.2.49 Reaction Kinetics in Waste and EBS – YMP 2.1.09.07.00

FEP Description: Chemical reactions, such as radionuclide dissolution/precipitation reactions and reactions controlling the reduction-oxidation state, may not be equilibrium in the drift and waste environment.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Effects of kinetics on waste-form dissolution reactions are considered in the in-package chemistry abstraction documented in F0170 (CRWMS M&O 2000w**)** supporting E0010 (CRWMS M&O 2000b). However, relative to the EBS modeling, subtleties of the reduction-oxidation reactions are only of interest if they actually significantly affect radionuclide transport. Use of experimentally derived Kds (reaction rate coefficients) already averages over interactions (and material heterogeneity). Thus, the specific effects of redox kinetics (separate from those incorporated in the data) are therefore excluded from the TSPA in E0010 (CRWMS M&O 2000b) on the basis of low consequence.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: RT1

References: E0010 (CRWMS M&O 2000b), F0170 (CRWMS M&O 2000w)

6.2.50 Chemical Gradients/Enhanced Diffusion in Waste and EBS – YMP 2.1.09.08.00

FEP Description: The existence of chemical gradients within the disposal system, induced naturally or resulting from repository material and waste emplacement, may influence the transport of contaminants of dissolved and colloidal species. This could include, for example, diffusion in and through failed canisters.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: In Yucca Mountain, the establishment of carrier plumes, each with the signature of the repository (with respect to temperature and chemistry-including hyperalkalinity), means that there are persistent chemical gradients, which identify the boundaries of the plumes. Sorption and reaction of contaminants with host rock occur within these plumes, at least until they become well-mixed with connate waters. Thus, the chemistry of the plumes is important, in contrast to the chemical gradients across their boundaries. At the present time, the waste form is represented by a mixing cell that conservatively assumes instantaneous chemical equilibrium. Chemical gradients and enhanced diffusion will have no impact on waste form performance. In addition, there is no flow resistance into or out of the failed waste packages, so advective transport will move radionuclides out of the failed containers at a much faster rate than would be calculated based on diffusion.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: ENFE4, RT1

References: E0095(CRWMS M&O 2000q), E0045 (CRWMS M&O 2000g)

6.2.51 Waste-Rock Contact – YMP 2.1.09.11.00

FEP Description: Waste and rock are placed in contact by mechanical failure of the drip shields and waste packages. Reactions between uranium, rock minerals, and water, in contact with both, precipitate uranium, leading spent fuel to dissolve more rapidly than if constrained by the equilibrium solubility of uranium.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Waste and rock could come in contact by mechanical failure of the drip shields and waste packages, although the extent of such direct interaction would be significantly limited by the intervening backfill. Reactions between uranium, rock minerals, and water, in contact with both, could precipitate uranium, leading spent fuel to dissolve more rapidly than if constrained by the equilibrium solubility of waste-form uranium phases. To the extent that such enhanced dissolution could occur, this is a waste form degradation issue and not modeled explicitly in the EBS analysis.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: ENFE3

References: E0010 (CRWMS M&O 2000b)

6.2.52 Rind (Altered Zone) Formation in Waste, EBS, and Adjacent Rock – YMP 2.1.09.12.00

FEP Description: Thermo-chemical processes involving precipitation, condensation, and redissolution alter the properties of the waste, EBS, and the adjacent rock. These alterations may form a rind, or altered zone, in the rock, with hydrological, thermal, and mineralogical properties different from the current conditions.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: The thermo-chemical-hydrological processes that will produce a rind are known to occur; the questions are, at what rate and to what depth. However, the effects of such a rind would manifest themselves as changes in the water seepage rate coming into the drift, the chemistry of that seepage, and the rate of gas influx. These parameters all represent boundary conditions to the EBS performance assessment. Thus, while this FEP may be of importance from an overall repository performance perspective, it is not germane to the EBS analysis other than through input from the NFE.

TSPA Disposition: This FEP is not directly relevant to modeling of the EBS other than through flow boundary conditions derived from the NFE.

IRSR Issues: None for EBS

References: E0100 (CRWMS M&O 2000r)

6.2.53 Complexation by Organics in Waste and EBS – YMP 2.1.09.13.00

FEP Description: The presence of organic complexants in water in the waste and EBS could augment radionuclide transport by providing a transport mechanism in addition to simple diffusion and advection of dissolved material. Organic complexants may include materials found in natural groundwater such as humates and fulvates, or materials introduced with the waste or engineered materials.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Complexation of radionuclides with organic species has been excluded from the TSPA on the basis of negligible consequences for two reasons. First, this mechanism would be most significant if it could alter the form of the dissolved radionuclides thereby reducing the likelihood of sorption in the invert. However, since sorption is presently ignored in the TSPA (see FEP 2.1.09.05.00), the transport of radionuclides is already maximized, and the neglect of complexation has no impact on the calculated release rate. Second, complexation in the immediate vicinity of the waste form could increase the rate of radionuclide release if the release rate is concentration limited. However, the low concentration of organics in the Yucca Mountain repository (CRWMS M&O 2000f) makes this effect negligible.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), E0040 (CRWMS M&O 2000f)

6.2.54 Colloid Formation in Waste and EBS – YMP 2.1.09.14.00

FEP Description: Colloids in the waste and EBS may affect radionuclide transport. Different types of colloids may exist initially or may form during the evolution of the system by a variety of mechanisms. This FEP aggregates all types of colloids into a single category. Technical discussions of colloids for the Yucca Mountain repository are presented separately for true colloids (FEP 2.1.09.15.00), natural pseudo-colloids (FEP 2.1.09.16.00), pseudo-colloids formed from corrosion products (FEP 2.1.09.17.00), and microbial colloids (FEP 2.1.09.18.00)

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: See separate discussion under FEPs 2.1.09.15.00, 2.1.09.16.00, 2.1.09.17.00, and 2.1.09.18.00.

TSPA Disposition: See separate discussion under FEPs 2.1.09.15.00, 2.1.09.16.00, 2.1.09.17.00, and 2.1.09.18.00.

IRSR Issues: RT1

References: E0010 (CRWMS M&O 2000b), E0045 (CRWMS M&2000g)

6.2.55 Formation of True Colloids in Waste and EBS – YMP 2.1.09.15.00

FEP Description: True colloids are colloidal-sized assemblages (between approximately 1 nanometer and 1 micrometer in diameter) of radionuclide-containing compounds. They may form in the waste and EBS during waste-form degradation and radionuclide transport. True colloids are also called radionuclide intrinsic colloids (or actinide intrinsic colloids, for those including actinide elements).

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: The formation of true colloids may occur as part of the waste form degradation process (as discussed in F0170 (CRWMS M&O 2000w)). Additional true colloid formation within the EBS is excluded in the TSPA on the basis of negligible consequences. This is because the EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000q) does not consider any retardation mechanisms that would cause radionuclides to precipitate out anywhere within the EBS. Thus, even if radionuclide-bearing true colloids were to form, it would not impact the radionuclide source term to the NFE as the rate of radionuclide transport is already maximized.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of negligible consequences.

IRSR Issues: RT1

References: E0095 (CRWMS M&O 2000q), F0170 (CRWMS M&O 2000w)

6.2.56 Formation of Pseudo-colloids (natural) in Waste and EBS – YMP 2.1.09.16.00

FEP Description: Pseudo-colloids are colloidal-sized assemblages (between approximately 1 nanometer and 1 micrometer in diameter) of nonradioactive material that has radionuclides bound to it. Pseudo-colloids include microbial colloids, mineral fragments, and humic and fulvic acids. This FEP addresses radionuclide-bearing colloids formed from host-rock materials and all interactions of the waste and EBS with the host rock environment except corrosion. Pseudo-colloids formed from corrosion of the waste form and EBS are discussed in FEP 2.1.09.17.00. Microbial colloids are discussed in FEP 2.1.09.18.00.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Natural colloids (clay, silica, and iron oxyhydroxides) may be transported in groundwater into the repository from the vadose zone above it or may be formed from the erosion of natural backfill and invert materials (e.g., crushed tuff). Pseudo-colloids may form due to the sorption onto these natural colloids of radionuclides mobilized from degradation of the waste form. Pseudo-colloids, thus formed in the waste and EBS, may influence radionuclide transport. Analyses and field studies show that radionuclides attached to colloids may be transported long distances relative to the aqueous radionuclide.

TSPA Disposition: The impact of natural pseudo-colloids on radionuclide transport is accounted for through the determination of colloid-associated radionuclide concentration limits (CRWMS M&O 2000v) the implementation of which is discussed in E0045 (CRWMS M&O

2000g).

IRSR Issues: RT1

References: E0010 (CRWMS M&O 2000b), E0045 (CRWMS M&O 2000g), CRWMS M&O 2000v

6.2.57 Formation of Pseudo-colloids (corrosion products) in Waste and EBS – YMP 2.1.09.17.00

FEP Description: Pseudo-colloids are colloidal-sized assemblages (between approximately 1 nanometer and 1 micrometer in diameter) of nonradioactive material that has radionuclides bound to it. Pseudo-colloids include microbial colloids, mineral fragments, and humic and fulvic acids. This FEP addresses pseudo-colloids such as iron oxyhydroxides formed from corrosion and degradation of the metals in the waste form and EBS. Radionuclide-bearing colloids formed from host-rock materials and all interactions of the waste and EBS with the host rock environment except corrosion are discussed in FEP 2.1.09.16.00. Microbial colloids are discussed in FEP 2.1.09.18.00.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Artificial materials (e.g., cement grout, carbon steel, stainless steel, aluminum, titanium-7, and Alloy-22) will be introduced during construction of the repository. The corrosion of these materials may produce significant quantities of colloids, primarily metal oxyhydroxides. Radionuclides will tend to sorb onto the colloids, forming pseudo-colloids as well as onto larger particles and scale. In addition, the degradation of waste glass and spent nuclear fuel will likely produce clays (with and possibly without entrained radionuclide-bearing phases), another "substrate" for pseudo-colloids in the drift. Pseudo-colloids thus formed in the waste and EBS may influence radionuclide transport. Analyses and field studies show that radionuclides attached to colloids may be transported long distances relative to the aqueous radionuclide.

TSPA Disposition: The impact of pseudo-colloids (from corrosion products) on radionuclide transport is accounted for through the determination of colloid-associated radionuclide concentration limits (CRWMS M&O 2000v), the implementation of which is discussed in E0045 (CRWMS M&O 2000g).

IRSR Issues: RT1

References: E0010 (CRWMS M&O 2000b), E0045 (CRWMS M&O 2000g), CRWMS M&O 2000v

6.2.58 Microbial Colloid Transport in the Waste and EBS – YMP 2.1.09.18.00

FEP Description: This FEP addresses the formation and transport of microbial colloids in the waste and EBS. Pseudo-colloids formed from corrosion and degradation of the metals in the waste form and EBS are discussed in FEP 2.1.09.16.00. Radionuclide-bearing colloids formed from host-rock materials and all interactions of the waste and EBS with the host rock environment except corrosion are discussed in FEP 2.1.09.17.00.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Microbes can affect the amount of mobile colloidal material such as clay, hematite, goethite, and silica by influencing the rate of waste package corrosion. Given the present state of knowledge, estimates of the effects of microbes on corrosion processes are highly uncertain. However, the quantities of microbes that will be available to accelerate corrosion rates are very low, as calculated in E0040 (CRWMS M&O 2000f). Also, microbial action tends to increase colloid size, which would result in increased gravitational settling and filtration. Therefore, exclusion of microbial effects from TSPA may be considered conservative. A more comprehensive discussion of such microbial colloids is presented in CRWMS M&O 2000v.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of negligible consequences.

IRSR Issues: RT1

References: E0010 (CRWMS M&O 2000b), E0045 (CRWMS M&O 2000g), E0040 (CRWMS M&O 2000f), CRWMS M&O 2000v

6.2.59 Colloid Transport and Sorption in the Waste and EBS – YMP 2.1.09.19.00

FEP Description: Interactions between radionuclide-bearing colloids and the waste and EBS may result in retardation of the colloids during transport by sorption mechanisms.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: The TSPA considers that all radionuclide-bearing colloids generated from waste form degradation within a failed waste package will leave the waste package and enter the drift and EBS. In reality, interactions between these radionuclide-bearing colloids and the waste and EBS would result in some retardation of the colloid transport by sorption mechanisms. However, as with in-drift sorption of dissolved radionuclides (FEP 2.1.09.05.00), this phenomenon is conservatively ignored.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low expected consequences, coupled with the fact that its exclusion is conservative.

IRSR Issues: RT1

References: E0010 (CRWMS M&O 2000b), E0045 (CRWMS M&O 2000g), E0095 (CRWMS M&O 2000q)

6.2.60 Colloid Filtration in the Waste and EBS – YMP 2.1.09.20.00

FEP Description: Filtration processes may affect transport of radionuclide-bearing colloids in the waste and EBS.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Transport of colloids within the EBS (within the tunnel) conservatively excludes consideration of colloid filtration. In this way, the rate of transport of radionuclides into the unsaturated zone is maximized.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low expected consequences, coupled with the fact that its exclusion is conservative.

IRSR Issues: RT1

References: E0010 (CRWMS M&O 2000b), E0045 (CRWMS M&O 2000g), E0095 (CRWMS M&O 2000q)

6.2.61 Suspensions of Particles Larger than Colloids – YMP 2.1.09.21.00

FEP Description: Groundwater flow through the waste could remove radionuclide-bearing particles by a rinse mechanism. Particles of radionuclide bearing material larger than colloids could then be transported in water flowing through the waste and EBS by suspension.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Suspension of radionuclide bearing particles in groundwater flowing downward through the invert could lead to an enhanced radionuclide source term at the UZ boundary. However, it is shown in CRWMS M&O 2000v that the suspension of particles larger than colloids in the UZ and saturated zone (SZ) can be excluded on the basis of consequences. Hence, any transport of such particulate within the tunnel is irrelevant to repository performance and can be excluded on the consequences.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: RT1

References: E0095 (CRWMS M&O 2000q), CRWMS M&O 2000v

6.2.62 Biological Activity in Waste and EBS – YMP 2.1.10.01.00

FEP Description: Biological activity in the waste and EBS may affect disposal-system performance by altering degradation processes such as corrosion of the waste packages and waste form (including cladding), by affecting radionuclide transport through the formation of colloids and biofilms, and by generating gases.

Note that this FEP also encompasses FEP ebs # 25 from table 3.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Microbes can affect the mobility of colloidal material, as well as influence the rate of waste package corrosion.

TSPA Disposition: The maximum mass of microbes is calculated in the *In-Drift Microbial Communities* AMR, E0040 (CRWMS M&O 2000f) and passed to the TSPA as a factor affecting patch corrosion of the drip shield and canister. A more comprehensive discussion of this FEP for all aspects of repository performance can be found in CRWMS M&O 2000v. It should be noted that this discussion concludes that from an overall repository performance perspective, this FEP can be excluded on the basis of consequences.

IRSR Issues: CLST1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), E0045 (CRWMS M&O 2000g), E0040 (CRWMS M&O 2000f), CRWMS M&O 2000v

6.2.63 Heat Output/Temperature in Waste and EBS – YMP 2.1.11.01.00

FEP Description: Temperature in the waste and EBS will vary through time. Heat from radioactive decay will be the primary cause of temperature change, but other factors to be considered in determining the temperature history include the in-situ geothermal gradient, thermal properties of the rock, EBS, and waste materials, hydrological effects, and the possibility of exothermic reactions (see FEP 2.1.11.03.00). Considerations of the heat generated by radioactive decay should take different properties of different waste types, including DSNF, into account.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Decay heat is a major issue in repository design, particularly at Yucca Mountain, where high loading densities and high temperatures are intended to be part of the waste isolation scheme.

TSPA Disposition: Relative to the performance assessment of the EBS, the temperature history is calculated explicitly as part of the *In-Drift Thermal-Hydrological-Chemical Model*, E0065 (CRWMS M&O 2000k).

IRSR Issues: TEF

References: E0065 (CRWMS M&O 2000k)

6.2.64 Exothermic Reactions in Waste and EBS – YMP 2.1.11.03.00

FEP Description: Exothermic reactions liberate heat and will alter the temperature of the disposal system and affect the properties of the repository and surrounding materials. Hydration of concrete used in the underground environment is an example of a possible exothermic reaction.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: A repository at Yucca Mountain is planned to be "hot." Maximum rock temperatures in the drift walls are expected to reach 165-185ºC (CRWMS M&O 2000k). The temperature changes suggested in this FEP are inconsequential by comparison.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: TEF

References: E0010 (CRWMS M&O 2000b), E0055 (CRWMS M&O 1999i), CRWMS M&O 2000k

6.2.65 Temperature Effects/Coupled Processes in Waste and EBS – YMP 2.1.11.04.00

FEP Description: This FEP broadly encompasses all coupled-process effects of temperature changes within the waste and EBS. Technical discussions relevant to this FEP are provided individually for each relevant process. See FEP 2.1.11.01.00 for a discussion of the temperature history of repository. See FEP 2.1.11.03.00 for a discussion of possible exothermic reactions. See FEP 2.1.11.05.00 for a discussion of the effects of differential thermal expansion of repository components. See FEP 2.1.11.07.00 for a discussion of thermally-induced stresses in the waste and EBS. See FEP 2.1.11.08.00 for a discussion of thermal effects on chemical and microbial processes. See FEP 2.1.11.09.00 for a discussion of thermal effects on fluid flow in the waste and EBS. See 2.1.11.10.00 for a discussion of the Soret effect.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Yucca Mountain evolves mechanically, chemically, and hydrologically under the influence of heat. This thermal evolution has a significant impact on all aspects of repository performance, including water seepage rates, corrosion rates, dissolution chemistry, etc. See discussion for each specific FEP identified in the FEP definition for more detail.

TSPA Disposition: The temperature history of the in-drift environment is calculated explicitly as part of the *In-Drift Thermal-Hydrological-Chemical Model*, E0065 (CRWMS M&O 2000k). Relative to EBS performance, the effect of this temperature history on chemistry is included in the rates of waste form degradation processes abstracted in F0170 (CRWMS M&O 2000w) and in the temperature-dependent equilibrium constants included in the geochemical models supporting the *EBS Physical and Chemical Environmental Abstraction Model,* E0010 (CRWMS M&O 2000b) and its submodels. See discussion for each specific FEP identified in the FEP definition for more detail.

IRSR Issues: TEF

References: E0065 (CRWMS M&O 2000k), E0010 (CRWMS M&O 2000b), F0170 (CRWMS M&O 2000w)

6.2.66 Differing Thermal Expansion of Repository Components – YMP 2.1.11.05.00

FEP Description: Thermally-induced stresses could alter the performance of the waste or EBS. For example, thermal stresses could create pathways for preferential fluid flow in the backfill or through the drip shield.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Thermal expansion induced failure (separation) of the drip shields has been screened out because the anticipated change in length is generally much less than the overlap between adjacent drip shields (see discussion in E0095 (CRWMS M&O 2000q)). Thermal expansion of other components, such as the waste package and pedestal, will not be a problem because the separation between adjacent waste packages is adequate to accommodate this small amount of expansion.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: CLST2, ENFE1, ENFE4, RDTME3

References: E0095 (CRWMS M&O 2000q)

6.2.67 Thermally-induced Stress Changes in Waste and EBS – YMP 2.1.11.07.00

FEP Description: Thermally-induced stress changes in the waste and EBS may affect performance of the repository. Relevant processes include rockfall, drift stability, changes in physical properties of the disturbed rock zone around the repository, and changes in the physical properties of the surrounding rock.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Repository heat at Yucca Mountain will drive the mechanical and chemical evolution of the repository and the mountain, producing durable changes. Thermal expansion (and thermo-mechanical coupling) is expected to rotate the least principal stress, currently NNW-SSE, to vertical, and after cooling, thermal contraction will rotate it back. Durable changes to the fracture flow systems are anticipated.

TSPA Disposition: Relative to the EBS analysis effort, the only relevant effect delineated above involves the impact of thermal stress on drift degradation (and thus rockfall). This is explicitly accounted for in the *Drift Degradation Analysis*, E0080 (CRWMS M&O 2000n). Impacts on the physical properties of the surrounding rock are implicitly accounted for, relative to EBS modeling, through changes in the water seepage influx boundary conditions from the NFE analysis.

IRSR Issues: CLST2, ENFE1, ENFE4, RDTME3

References: E0080 (CRWMS M&O 2000n)

6.2.68 Thermal Effects: Chemical and Microbiological Changes in the Waste and EBS – YMP 2.1.11.08.00

FEP Description: Temperature changes may affect chemical and microbial processes in the waste and EBS.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Chemical reaction and microbial process rates are very sensitive to temperature. Thus, this dependence must be accounted for.

TSPA Disposition: The effects of temperature on chemical reaction properties are included in the geochemical models supporting E0010 (CRWMS M&O 2000b) and its submodels. The effects of temperature on microbial growth are included in the *In-Drift Microbial Communities* AMR, E0040 (CRWMS M&O 2000f).

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b) and all its submodel abstractions

6.2.69 Thermal Effects on Liquid or Two-phase Fluid Flow in the Waste and EBS – YMP 2.1.11.09.00

FEP Description: Temperature differentials may result in convective flow in the waste and EBS.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Thermal effects may have an important influence on the rate of water contact with the waste package and/or drip shield (thereby influencing the corrosion rate) and on the rate of water influx into a failed waste package (thereby influencing the rate of waste form dissolution). Examples of this include localized dryout in the immediate vicinity of the waste packages during the early thermal phase of the repository history, as well as evaporation condensation on the underside of the drip shield providing an additional source term of water for dripping onto the waste package.

TSPA Disposition: Thermal effects on liquid or two-phase flow within the waste and EBS are explicitly accounted for in the *In-Drift Thermal-Hydrological-Chemical Model*, E0065 (CRWMS M&O 2000k). This includes consideration of dryout near the waste packages, as well as evaporation/condensation within the drift and underneath the drip shield. The results of these analyses then feed the *EBS Radionuclide Transport Abstraction*, E0095 (CRWMS M&O 2000q).

IRSR Issues: ENFE1, ENFE2, ENFE3, RT1

References: E0065 (CRWMS M&O 2000k), E0095 (CRWMS M&O 2000q)

6.2.70 Thermal Effects on Diffusion (Soret effect) in Waste and EBS – YMP 2.1.11.10.00

FEP Description: The Soret effect is a diffusion process caused by a thermal gradient. In liquids having both light and heavy molecules (or ions), the heavier molecules tend to concentrate in the cold region. Temperature differences in the waste and EBS may result in a component of diffusive solute flux that is proportional to the temperature gradient.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: The potential for the Soret effect should be greatest during the first 3,000 years when the maximum thermal response occurs in the repository (CRWMS M&O 2000k). However, during this time, the waste packages and drip shields will be essentially intact, and thus there will be near-zero release during this time. Later in time, the thermal gradients within the EBS are reduced. Further, the seepage flow conditions are such that the invert (the primary region through which contaminant transport occurs) is expected to remain unsaturated, further minimizing the likelihood of thermally-driven diffusion. In light of the various simplifying, conservative assumptions currently made in the *EBS Radionuclide Transport Abstraction*, E0095 (CRWMS M&O 2000q), which includes full advective transport of all radionuclides released from the waste form with no consideration of delay mechanisms such as sorption, the neglect of the Soret effect is considered to be of negligible consequences.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: ENFE1, ENFE4, RT1

References: E0095 (CRWMS M&O 2000q)

6.2.71 Gas Generation – YMP 2.1.12.01.00

FEP Description: Gas may be generated in the repository by a variety of mechanisms. Gas generation might lead to pressurization of the repository, produce multiphase flow, and affect radionuclide transport. This FEP aggregates all types of gas generation into a single category. Technical discussions are presented separately for gas generation from fuel decay (FEP 2.1.12.02.00), corrosion (FEP 2.1.12.03.00), microbial degradation (FEP 2.1.12.04.00), concrete (FEP 2.1.12.02.05.00), radioactive gases within the waste (FEP 2.1.12.07.00), and radiolysis (2.1.13.01.00).

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Because the repository would be in the UZ, which is well connected to the surface, gas produced by whatever reaction is expected to escape or at least be only temporarily confined beneath the condensate zone above the drifts. Gas permeability, as measured in pneumatic tests, is believed to be adequate to allow escape. The calculation of the specific gas flux and composition within the EBS is delineated in the *In-Drift Gas Flux and Composition*, E0035 (CRWMS M&O 2000 e), which supports the *EBS Physical and Chemical Environmental Abstraction Model,* E0010 (CRWMS M&O 2000b).

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: RT1

References: E0010 (CRWMS M&O 2000b), E0035 (CRWMS M&O 2000e)

6.2.72 Gas Generation (He) from Fuel Decay – YMP 2.1.12.02.00

FEP Description: Helium (He) gas production may occur by alpha decay in the fuel. He production might cause local pressure buildup in cracks in the fuel and in the void between fuel and cladding, leading to cladding failure.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: He production is a result of alpha decay of actinides, so it is a consequence of the decay process. This He production could manifest itself in one of two ways. First, it could result in earlier failure of commercial spent nuclear fuel cladding as a result of higher internal gas pressures. This is a WF issue, and is discussed in the WF FEPs summary (CRWMS M&O 2000x). The second effect could be as another source of gas generation that might lead to pressurization of the repository (see FEP 2.1.12.01.00). This latter effect has already been screened out because of the placement of the drift within the UZ of the repository. Because of the inert nature of the He gas, no chemical effects (water chemistry changes) are expected.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: RT1

References: E0010 (CRWMS M&O 2000b), E0035 (CRWMS M&O 2000e), CRWMS M&O 2000x

6.2.73 Gas Generation (H2) from Metal Corrosion – YMP 2.1.12.03.00

FEP Description: Gas generation can affect the mechanical behavior of the host rock and engineered barriers, chemical conditions, and brine flow, and, as a result, the transport of radionuclides. Gas generation due to oxic corrosion of waste containers, cladding, and/or structural materials will occur at early times following closure of the repository. Anoxic corrosion may follow the oxic phase, if all oxygen is depleted. The formation of a gas phase around the canister may even exclude water from the iron, thus inhibiting further corrosion.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Gas generated from corrosion of metal components within the EBS can have three influences; the hydrogen generated may impact the chemistry of the seepage flow within the drift, the hydrogen generated may blanket the metal structure and inhibit further corrosion, and the gas generated may be another contributor to potential repository pressurization. Since a repository in Yucca Mountain would be located in the UZ and therefore be well-connected to the atmosphere, it is not expected that the oxidation state of the groundwater would be affected. The primary effect may be to cause some embrittlement of the metal structures, but this is only of potential significance to the waste package and drip shield (a WP issue). The potential blanketing of the metal structure with hydrogen gas, thereby inhibiting further corrosion, is conservatively ignored. Finally, the last effect (repository pressurization) has already been screened out (see FEP 2.1.12.01.00) because of the placement of the drift within the UZ of the repository.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: RT1

References: E0010 (CRWMS M&O 2000b), E0035 (CRWMS M&O 2000e)

6.2.74 Gas Generation (CO2, CH4, H2S) from Microbial Degradation – YMP 2.1.12.04.00

FEP Description: Microbial breakdown of cellulosic material, and possibly plastics and other synthetic materials, will produce mainly CO_2, but also other gases. The rate of microbial gas production will depend upon the nature of the microbial populations established, the prevailing conditions (temperature, pressure, geochemical conditions), and the substrates present.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: A maximum value has been set on the quantity of organic materials that could be left in the repository at the time of closure (CRWMS M&O 1995b). Further, the level of microbial activity, as discussed in E0040 (CRWMS M&O 2000f), is expected to be low. Hence, the quantity of gases generated due to microbial activity is expected to be small. As discussed for FEP 2.1.12.01.00, any such gas generated would have negligible impact on repository performance because of its being situated in the UZ.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: RT1

References: E0010 (CRWMS M&O 2000b), E0040 (CRWMS M&O 2000f), E0035 (CRWMS M&O 2000e)

6.2.75 Gas Generation from Concrete – YMP 2.1.12.05.00

FEP Description: Production of gases from the aging and degradation of concrete may occur through radiolysis of water in the cement pore spaces and microbial growth on concrete.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: At Yucca Mountain, decomposition of concrete by radiolysis is not considered, because the only cementitious material (grout around rock bolts) is located far from any radioactive waste forms. In addition, the repository location in the UZ reduces the dominance of aqueous corrosion. The character of the cementitious material degradation processes is delineated in the *Seepage/Cement Interactions Abstraction,* E0055 (CRWMS M&O 2000i). While the impact of these interactions on water chemistry is accounted for, the impact of the generated gases is ignored. As discussed for FEP 2.1.12.01.00, any such gas generated would have negligible impact on repository performance because of its being situated in the UZ.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: RT1

References: E0010 (CRWMS M&O 2000b), E0055 (CRWMS M&O 2000i), E0035 (CRWMS M&O 2000e)

6.2.76 Gas Transport in Waste and EBS – YMP 2.1.12.06.00

FEP Description: Gas in the waste and engineered barrier system could affect the long-term performance of the disposal system. Radionuclides may be transported as dissolved gases or in gas bubbles. These may affect flow paths, and two-phase flow conditions may be important.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: The only normally occurring gases of concern at Yucca Mountain are $14CO_2$, various radioactive fission gases, and Radon. For a repository in the UZ, these readily escape to the atmosphere. Thus, no significant gas buildup within the EBS occurs, and impact on flow paths is negligible.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: RT1

References: E0010 (CRWMS M&O 2000b), E0035 (CRWMS M&O 2000e)

6.2.77 Radioactive Gases in Waste and EBS – YMP 2.1.12.07.00

FEP Description: Radioactive gases may exist or be produced in the repository. These gases may subsequently escape from the repository. Typical radioactive gases include 14-C (in $14CO_2$ and $14CH_4$) produced during microbial degradation, tritium, fission gases (Ar, Xe, Kr), and radon.

Screening Decision: Exclude (for EBS)

Screening Decision Basis: Low Consequences

Screening Argument: The radioactive gases are $14CO_2$ and $14CH_4$, fission gases (Ar, Xe, Kr) and radon (Rn). The CO_2, CH_4 and fission gases will in part escape from the mountain. To the extent that these have a significant contribution on the calculated source term, they are considered in the TSPA. Relative to the impact of these gases on repository performance due to pressurization effects, they are ignored. As discussed for FEP 2.1.12.01.00, any such gas generated would have negligible impact on repository performance because of its being situated in the UZ.

TSPA Disposition: This FEP is excluded from the TSPA (for the EBS) on the basis of low consequences.

IRSR Issues: RT1

References: E0010 (CRWMS M&O 2000b), E0035 (CRWMS M&O 2000e)

6.2.78 Gas Explosions – YMP 2.1.12.08.00

FEP Description: Explosive gas mixtures could collect in the sealed repository. An explosion in the repository could have radiological consequences if the structure of the repository were damaged or near-field processes enhanced or inhibited.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: As discussed under FEPs YMP 2.1.12.01-05, there are a number of sources for gas generation, some of which result in the production of flammable gases (H_2, CH_4, and C_2H_2). Generally however, the permeability of Yucca Mountain to air will provide an adequate condition for the flammable/explosive gases to be diluted, diffused, and/or dispersed before they could reach explosive concentrations. Possibly, gases, as well as water, could accumulate, if there was a condensation cap or reduced permeability. However, no viable ignition source can be identified. Further, the possibility of a condensation cap has been essentially eliminated in the current design by greatly increasing the distance between the disposal tunnels (CRWMS M&O 1999f). The possibility of reduced permeability to gas would also limit the availability of oxygen for combustion and greatly reduce the corrosion of containers, thereby reducing the number of containers potentially producing flammable/explosive gases.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: RT1

References: CRWMS M&O 1999f

6.2.79 Radiolysis – YMP 2.1.13.01.00

FEP Description: Alpha, beta, gamma, and neutron irradiation of water can cause dissociation of molecules, leading to gas production and changes in chemical conditions (Eh, pH, concentration of reactive radicals).

Screening Decision: Exclude for EBS

Screening Decision Basis: N/A to EBS

Screening Argument: Radiolysis occurs around the container and may produce more aggressive fluids. Only radiolysis due to gamma and neutron radiation is possible as long as the container is intact. It will have some impact on water chemistry in the vicinity of the canister. The effects of radiolysis would be included in the integrated corrosion models for the waste package and drip shield. See the WP FEPs summary (CRWMS M&O 2000dd) for a discussion of this phenomenon. Related FEPs are discussed under 2.1.12.01.00 (gas generation) and 2.1.09.06.00 (redox potential in waste and EBS). Alpha and beta radiolysis, occurring up to .03 mm from the fuel pellets, will be of importance after canister failure, when water gets in close contact with the fuel matrix. For a discussion of this relative to its impact on waste form degradation, see the WF FEPs summary (CRWMS M&O 2000x).

TSPA Disposition: Excluded for the EBS analysis.

IRSR Issues: ENFE2, ENFE3, RT1

References: CRWMS M&O 2000x, CRWMS M&O 2000dd

6.2.80 Radiation Damage in Waste and EBS – YMP 2.1.13.02.00

FEP Description: Strong radiation fields could lead to radiation damage to the waste forms and containers (CSNF, DSNF, DHLW), backfill, drip shield, seals, and surrounding rock.

Screening Decision: Exclude (backfill, seals, pedestal, etc.)

Screening Decision Basis: Low Consequences

Screening Argument: Radiation damage that affects mobilization of contaminants is included in the data describing such mobilization and is therefore implicitly included in modeling. Further, this is a WF issue as discussed in the WF FEPs summary (CRWMS M&O 2000x). Radiation damage to the waste packages and/or drip shields is a WP issue as discussed in the WP FEPs summary (CRWMS M&O 2000dd). Radiation damage to other EBS structural components is expected to be negligible. Further, even if there were any damage to the pedestal, its failure is already assumed in the *EBS Radionuclide Transport Abstraction,* E0095 (CRWMS M&O 2000q). Thus, the consequences associated with this FEP relative to pedestal failure are already bounded in the current TSPA analysis.

TSPA Disposition: This FEP is excluded form the TSPA on the basis of low consequences (included via bounding assumptions).

IRSR Issues: All

References: E0095 (CRWMS M&O 2000q), CRWMS M&O 2000x, CRWMS M&O 2000dd

6.2.81 Mutation – YMP 2.1.13.03.00

FEP Description: Radiation fields could cause mutation of micro-organisms, leading to unexpected chemical reactions and impacts.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Microbes can affect the mobility of colloidal material as well as influence the rate of waste package corrosion. Given present knowledge, estimates of the effects of microbes on corrosion processes are highly uncertain; the potential effects of mutated microbes are more uncertain. No analyses or experimental research have been performed to investigate this problem specifically. However, general principles of population genetics indicate that most mutations are either neutral or deleterious to the fitness of an organism and, in the absence of strong natural selection, are unlikely to produce any definite change in the phenotypes of the organisms. Thus, exclusion of effects of mutated microbes from TSPA is considered to be conservative.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: CLST1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), E0040 (CRWMS M&O 2000f)

6.2.82 Episodic/Pulse Release from Repository – YMP 2.2.07.06.00

FEP Description: Episodic release of radionuclides from the repository and radionuclide transport in the UZ may occur both because of episodic flow into the repository, and because of other factors including intermittent failures of waste packages.

Note that this FEP also encompasses FEP ebs # 16 from table 3.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Pulse releases have been screened out because a bathtub model, which would generate a pulse release, has been shown to be nonconservative relative to the flow-through model used in the *EBS Radionuclide Transport Abstraction*, E0095 (CRWMS M&0 2000q).

TSPA Disposition: Episodic flow is explicitly included through climate change and its impact on seepage inflow to the drifts (boundary condition from the NFE analysis). Pulse releases are screened out on the basis of low consequences.

IRSR Issues: RT1

References: E0095 (CRWMS M&O 2000q)

6.2.83 Redissolution of Precipitates Directs More Corrosive Fluids to Containers – YMP 2.2.08.04.00

FEP Description: Redissolution of precipitates that have plugged pores as a result of evaporation of groundwater in the hot zone, produces a pulse of fluid reaching the waste containers when gravity-driven flow resumes, which is more corrosive than the original fluid in the rock.

Screening Decision: Include

Screening Decision Basis: N/A

Screening Argument: Re-establishment of flow will occur through the mode with the highest permeability, fractures through which flow persisted or which were easily unplugged. Plugged pores are least likely to reopen because there is no flow to dissolve the precipitates. Flow is likely to have chemistry associated with redissolution; however, it is still likely that the chemistry of the fluids will be driven by interaction with the drift liner, dissolved constituents such as Fe and the residual temperature of the repository.

TSPA Disposition: The occurrence of pulses of corrosive fluids is implicit in the in-drift water fluxes developed in E0095 (CRWMS M&O 2000q) and the water compositions resulting from in-drift precipitates/salts analysis in E0105 (CRWMS M&O 2000s), both supporting E0100 (CRWMS M&O 2000b).

IRSR Issues: ENFE1, ENFE3, ENFE4, RT1

References: E0095 (CRWMS M&O 2000q), E0010 (CRWMS M&O 2000b), E0105 (CRWMS M&O 2000s)

6.2.84 Gas Pressure Effects – YMP 2.2.11.02.00

FEP Description: Pressure variations due to gas generation may affect flow patterns and contaminant transport in the geosphere.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: For a repository located in the UZ at Yucca Mountain, the connections to the atmosphere assure that a significant buildup of gas pressure is not likely.

Studies on 2-phase flow are, however, just beginning to consider certain special aspects of the problem.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: RT1

References: E0035 (CRWMS M&O 2000e)

6.2.85 Drains – ebs # 23

FEP Description: Water accumulation in the drift would wet the invert materials, possibly pond, and provide a continuing source of water vapor beneath the drip shield and backfill for interaction with waste packages and their supports. Engineered drains are a consideration for mitigating such water accumulation and ponding.

Screening Decision: Exclude

Screening Decision Basis: Low (Zero) Probability

Screening Argument: Drains are not part of the baseline design (CRWMS M&O 1999f). Thus this FEP is not relevant to the YMP design, and the probability is by definition zero.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not relevant to YMP design).

IRSR Issues: None

References: (CRWMS M&O 1999f)

6.2.86 Drainage with Transport – Sealing and Plugging – ebs # 27

FEP Description: Normal functioning of drainage in the drifts is not established, so how drainage will change if fractures are plugged is unclear. Suggestions include ponding until fractures in the wall are reached by the water level or until there is sufficient head to clear the fractures.

Screening Decision: Exclude

Screening Decision Basis: Low Consequences

Screening Argument: Transport of contaminants to the drift floor could result in a layer of sediment on the floor or in blockage of the fractures in the floor. This combined with floor buckling could result in localized regions of water accumulation. However, the extent of such ponding is expected to be very small. Further, the waste packages would still sit above the buckled floor, and thus would not be immersed in water. Thus, the fraction of waste packages in continuous contact with water would be negligible and the effect on radionuclide release and hence dose is expected to be negligible.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequences.

IRSR Issues: None

References: (CRWMS M&O 2000q)

7. CONCLUSIONS

Table 5 provides a summary of the EBS FEP screening decisions and the basis for "Exclude" decisions.

Table 5. Summary of EBS FEP Screening Decisions

YMP FEP #	FEP Name - YMP FEP #	Screening Decision	Screening Basis
YMP 1.1.02.00.00	Excavation/Construction	Exclude	Low Consequences
YMP 1.1.02.01.00	Site Flooding (During Construction and Operation)	Exclude	Regulatory
YMP 1.1.02.02.00	Effects of Preclosure Ventilation	Include	
YMP 1.1.02.03.00	Undesirable Materials Left	Exclude	Low Consequences
YMP 1.1.03.01.00	Error in Waste or Backfill Emplacement	Exclude	Regulatory
YMP 1.1.07.00.00	Repository Design	Include	(a)
YMP 1.1.08.00.00	Quality Control	Include	(a)
YMP 1.1.12.01.00	Accidents and Unplanned Events During Operation	Exclude	Regulatory
YMP 1.1.13.00.00	Retrievability	Include	(a)
YMP 1.2.04.03.00	Igneous Intrusion into Repository	Exclude (for EBS)	N/A – see DE PMR (b)
YMP 2.1.03.01.00	Corrosion of Waste Containers	Include	Also see WP PMR (c)
YMP 2.1.03.10.00	Container Healing	Include	Also see WP PMR (c)
YMP 2.1.03.12.00	Container Failure (Long-term)	Include	Also see WP PMR (c)
YMP 2.1.04.01.00	Preferential Pathways in the Backfill	Include	
YMP 2.1.04.02.00	Physical and Chemical Properties of Backfill	Include	
YMP 2.1.04.03.00	Erosion or Dissolution of Backfill	Exclude	Low Consequences
YMP 2.1.04.04.00	Mechanical Effects of Backfill	Include	
YMP 2.1.04.05.00	Backfill Evolution	Include	
YMP 2.1.04.06.00	Properties of Bentonite	Exclude	Zero Probability (d)
YMP 2.1.04.07.00	Buffer Characteristics	Exclude	Zero Probability (d)
YMP 2.1.04.08.00	Diffusion in Backfill	Exclude	Low Consequences

Table 5. Summary of EBS FEP Screening Decisions - Continued

YMP FEP #	FEP Name - YMP FEP #	Screening Decision	Screening Basis
YMP 2.1.04.09.00	Radionuclide Transport Through Backfill	Exclude	Low Consequences
YMP 2.1.06.01.00	Degradation of Cementitious Materials in Drift	Include	
YMP 2.1.06.02.00	Effects of Rock Reinforcement Materials	Include	
YMP 2.1.06.03.00	Degradation of the Liner	Exclude	Zero Probability (d)
YMP 2.1.06.04.00	Flow Through the Liner	Exclude	Zero Probability (d)
YMP 2.1.06.05.00	Degradation of Invert and Pedestal	Include	
YMP 2.1.06.06.00	Effects and Degradation of Drip Shield	Include	
YMP 2.1.06.07.00	Effects at Material Interfaces	Exclude	Low Consequences
YMP 2.1.07.01.00	Rockfall (Large Block)	Exclude	Low Consequences
YMP 2.1.07.02.00	Mechanical Degradation or Collapse of Drift	Exclude	Low Consequences
YMP 2.1.07.03.00	Movement of Containers	Include	
YMP 2.1.07.04.00	Hydrostatic Pressure on Container	Exclude	Zero Probability (d)
YMP 2.1.07.05.00	Creeping of Metallic Materials in the EBS	Exclude	Low Consequences
YMP 2.1.07.06.00	Floor Buckling	Exclude	Low Consequences
YMP 2.1.08.01.00	Increased Unsaturated Water Flux at the Repository	Include	
YMP 2.1.08.02.00	Enhanced Influx (Philip's Drip)	Exclude	Low Consequences
YMP 2.1.08.04.00	Condensation Forms on Backs of Drifts	Include	
YMP 2.1.08.05.00	Flow Through Invert	Include	
YMP 2.1.08.06.00	Wicking in Waste and EBS	Include	
YMP 2.1.08.07.00	Pathways for Unsaturated Flow and Transport in the Waste and EBS	Include	
YMP 2.1.08.08.00	Induced Hydrological Changes in the Waste and EBS	Include	
YMP 2.1.08.09.00	Saturated Groundwater Flow in Waste and EBS	Exclude	Low Consequences
YMP 2.1.08.11.00	Resaturation of Repository	Include	
YMP 2.1.09.01.00	Properties of the Potential Carrier Plume in the Waste and EBS	Include	
YMP 2.1.09.02.00	Interaction with Corrosion Products	Include	
YMP 2.1.09.05.00	In-drift Sorption	Exclude	Low Consequences
YMP 2.1.09.06.00	Reduction-oxidation Potential in Waste and EBS	Include	
YMP 2.1.09.07.00	Reaction Kinetics in Waste and EBS	Exclude	Low Consequences
YMP 2.1.09.08.00	Chemical Gradients/Enhanced Diffusion in Waste and EBS	Exclude	Low Consequences
YMP 2.1.09.11.00	Waste-Rock Contact	Exclude	Low Consequences
YMP 2.1.09.12.00	Rind (Altered Zone) Formation in Waste, EBS, and Adjacent Rock	Include	
YMP 2.1.09.13.00	Complexation by Organics in Waste and EBS	Exclude	Low Consequences

Table 5. Summary of EBS FEP Screening Decisions - Continued

YMP FEP #	FEP Name - YMP FEP #	Screening Decision	Screening Basis
YMP 2.1.09.14.00	Colloid Formation in Waste and EBS	Include	
YMP 2.1.09.15.00	Formation of True Colloids in Waste and EBS	Exclude	Low Consequences
YMP 2.1.09.16.00	Formation of Pseudo-colloids (Natural) in Waste and EBS	Include	
YMP 2.1.09.17.00	Formation of Pseudo-colloids (Corrosion Products) in Waste and EBS	Include	
YMP 2.1.09.18.00	Microbial Colloid Transport in the Waste and EBS	Exclude	Low Consequences
YMP 2.1.09.19.00	Colloid Transport and Sorption in the Waste and EBS	Exclude	Low Consequences
YMP 2.1.09.20.00	Colloid Filtration in the Waste and EBS	Exclude	Low Consequences
YMP 2.1.09.21.00	Suspensions of Particles Larger than Colloids	Exclude	Low Consequences
YMP 2.1.10.01.00	Biological Activity in Waste and EBS	Include	
YMP 2.1.11.01.00	Heat Output / Temperature in Waste and EBS	Include	
YMP 2.1.11.03.00	Exothermic Reactions in Waste and EBS	Exclude	Low Consequences
YMP 2.1.11.04.00	Temperature Effects / Coupled Processes in Waste and EBS	Include	
YMP 2.1.11.05.00	Differing Thermal Expansion of Repository Components	Exclude	Low Consequences
YMP 2.1.11.07.00	Thermally-induced Stress Changes in Waste and EBS	Include	
YMP 2.1.11.08.00	Thermal Effects: Chemical and Microbiological Changes in the Waste and EBS	Include	
YMP 2.1.11.09.00	Thermal Effects on Liquid or Two-phase Fluid Flow in the Waste and EBS	Include	
YMP 2.1.11.10.00	Thermal Effects on Diffusion (Soret effect) in Waste and EBS	Exclude	Low Consequences
YMP 2.1.12.01.00	Gas Generation	Exclude	Low Consequences
YMP 2.1.12.02.00	Gas Generation (He) from Fuel Decay	Exclude	Low Consequences
YMP 2.1.12.03.00	Gas Generation (H_2) from Metal Corrosion	Exclude	Low Consequences
YMP 2.1.12.04.00	Gas Generation (CO_2, CH_4, H_2S) from Microbial Degradation	Exclude	Low Consequences
YMP 2.1.12.05.00	Gas Generation from Concrete	Exclude	Low Consequences
YMP 2.1.12.06.00	Gas Transport in Waste and EBS	Exclude	Low Consequences
YMP 2.1.12.07.00	Radioactive Gases in Waste and EBS	Exclude (for EBS)	Low Consequences
YMP 2.1.12.08.00	Gas Explosions	Exclude	Low Consequences
YMP 2.1.13.01.00	Radiolysis	Exclude (for EBS)	N/A – see WF PMR (b)
YMP 2.1.13.02.00	Radiation Damage in Waste and EBS	Exclude	Low Consequences
YMP 2.1.13.03.00	Mutation	Exclude	Low Consequences
YMP 2.2.07.06.00	Episodic / Pulse Release from Repository	Include	(also see NFE PMR)
YMP 2.2.08.04.00	Redissolution of Precipitates Directs More Corrosive Fluids to Containers	Include	

Table 5. Summary of EBS FEP Screening Decisions - Continued

YMP FEP #	FEP Name - YMP FEP #	Screening Decision	Screening Basis
YMP 2.2.11.02.00	Gas Pressure Effects	Exclude	Low Consequences
New – ebs # 23	Drains	Exclude	Zero Probability (d)
New – ebs # 27	Drainage with Transport – Sealing and Plugging	Exclude	Low Consequences

(a) – Part of baseline design.
(b) – While the identified FEP may be important for TSPA, it is not important to modeling of the EBS.
(c) – These are primarily WP FEPs; the EBS analysis merely provides the appropriate boundary conditions.
(d) – This potential repository feature is not part of the baseline design.

8. REFERENCES

8.1 DOCUMENTS CITED

Cranwell, R.M.; Guzowski, R.W.; Campbell, J.E.; and Ortiz, N.R. 1990. *Risk Methodology for Geologic Disposal of Radioactive Waste: Scenario Selection Procedure*. NUREG/CR-1667. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: NNA.19900611.0073.

CRWMS M&O 1995a. *Total System Performance Assessment - 1995: An Evaluation of the Potential Yucca Mountain Repository*. B00000000-01717-2200-00136 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19960724.0188.

CRWMS M&O 1995b. *Waste Isolation Evaluation: Tracers, Fluids, and Materials, and Excavation Methods for Use in the Package 2C Exploratory Studies Facility Construction*. BABE00000-01717-2200-00007 REV 04. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19950721.0172.

CRWMS M&O 1999a. *EBS FEPs/Degradation Modes Abstraction*. TDP-WIS-PA-000002 Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991117.0158.

CRWMS M&O 1999b. *License Application Design Selection Report*. B00000000-01717-4600-00123 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990511.0325.

CRWMS M&O 1999c. *YMP FEP Database Rev 00C*. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991214.0518; MOL.19991214.0519.

CRWMS M&O 1999d. *In Drift Corrosion Products*. ANL-EBS-MD-000041 Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000106.0438.

CRWMS M&O 1999e. *Conduct of Performance Evaluation*. Activity Evaluation, September 30, 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991028.0092.

CRWMS M&O 1999f. *Monitored Geologic Repository Project Description Document.* B00000000-01717-1705-00003 REV 00 DCN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991117.0160.

CRWMS M&O 2000a. *Invert Diffusion Properties Model*. ANL-EBS-MD-000031 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000203.0694.

CRWMS M&O 2000b. *Physical and Chemical Environment Abstraction Model*. ANL-EBS-MD-000046 REV 00. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0043.

CRWMS M&O 2000c. *Engineered Barrier System Features, Events and Processes and Degradation Modes Analysis*. ANL-EBS-MD-000035 Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000217.0216.

CRWMS M&O 2000d. *Seepage/Backfill Interactions*. ANL-EBS-MD-000039 REV 00. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0194.

CRWMS M&O 2000e. *In-Drift Gas Flux & Composition*. ANL-EBS-MD-000040 REV 00. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0195.

CRWMS M&O 2000f. *In-Drift Microbial Communities*. ANL-EBS-MD-000038 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000331.0661.

CRWMS M&O 2000g. *In-Drift Colloids and Concentrations*. ANL-EBS-MD-000042 REV 00. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0196.

CRWMS M&O 2000h. *EBS Radionuclide Transport Model*. ANL-EBS-MD-000034 REV 00. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0225.

CRWMS M&O 2000i. *Seepage/Cement Interactions*. ANL-EBS-MD-000043 REV 00. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0123.

CRWMS M&O 2000j. *Seepage/Invert Interactions*. ANL-EBS-MD-000044 REV 00. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0197.

CRWMS M&O 2000k. *In-Drift Thermal-Hydrological-Chemical Model.* ANL-EBS-MD-000026 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000113.0488.

CRWMS M&O 2000l. *Water Drainage Model*. ANL-EBS-MD-000029 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000117.0216.

CRWMS M&O 2000m. *Ventilation Model*. ANL-EBS-MD-000030 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000107.0330.

CRWMS M&O 2000n. *Drift Degradation Analysis*. ANL-EBS-MD-000027 Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000107.0328.

CRWMS M&O 2000o. *Water Diversion Model*. ANL-EBS-MD-000028 Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000107.0329.

CRWMS M&O 2000p. *Water Distribution and Removal Model*. Input Transmittal 00219.T. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000410.0835.

CRWMS M&O 2000q. *EBS Radionuclide Transport Abstraction*. ANL-WIS-PA-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0208.

CRWMS M&O 2000r. *Physical and Chemical Environment Model*. Input Transmittal 00224.T. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000412.0789.

CRWMS M&O 2000s. *In-Drift Precipitates/Salts Analysis*. ANL-EBS-MD-000045 REV 00. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0198.

CRWMS M&O 2000t. *Multiscale Thermohydrologic Model*. ANL-EBS-MD-000049 REV 00. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0019.

CRWMS M&O 2000u. *Abstraction of Near-Field Environment Drift Thermodynamic Environment and Percolation Flux*. ANL-EBS-HS-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0039.

CRWMS M&O 2000v. *Waste Form Colloid-Associated Concentration Limits: Abstraction and Summary*. Input Transmittal 00175.T. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000328.0644.

CRWMS M&O 2000w. *In-Package Chemistry Abstraction for TSPA-LA*. Input Transmittal 00163.T. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000327.0214.

CRWMS M&O 2000x. *Miscellaneous Waste Form FEPs*. Input Transmittal 00149.T. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000317.0471.

CRWMS M&O 2000y. *Features, Events, and Processes in Thermal Hydrology and Coupled Processes*. Input Transmittal 00221.T. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000411.0231.

CRWMS M&O 2000z. *Disruptive Events FEPS*. ANL-WIS-MD-000005 REV 00. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0017.

CRWMS M&O 2000aa. *Abstraction of Drift Seepage*. ANL-NBS-MD-000005 Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000322.0671.

CRWMS M&O 2000bb. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0059.

CRWMS M&O 2000cc. *WAPDEG Analysis of Waste Package and Drip Shield Degradation*. ANL-EBS-PA-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0044.

CRWMS M&O 2000dd. *FEPS Screening of Processes and Issues in Drip Shield and Waste Package Degradation*. Input Transmittal 00150.T. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000317.0480.

CRWMS M&O 2000ee. *Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier*. ANL-EBS-MD-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000328.0590.

CRWMS M&O 2000ff. *Incorporation of Uncertainty and Variability of Drip Shield and Waste Package Degradation in WAPDEG Analysis*. Input Transmittal 00142.T. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000317.0478.

CRWMS M&O 2000gg. *Subsurface Facility System Description Document.* SDD-SFS-SE-000001 REV00. Volume I. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000221.0712.

CRWMS M&O 2000hh. *Ground Control System Description Document.* SDD-GCS-SE-000001 REV00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000221.0711.

DOE (U.S. Department of Energy) 1996. *Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant.* DOE/CAO-1996-2184. Carlsbad, New Mexico: U.S. Department of Energy, Carlsbad Area Office. TIC: 240511.

Philip, J.R., Knight, J.H., and Waechter, R.T., 1989. "Unsaturated Seepage and Subterranean Holes: Conspectus, and Exclusion Problem for Circular Cylindrical Cavities," *Water Resources Research, 25* (1), 16-28, Washington, D.C.: American Geophysical Union. TIC: 239117.

SAM (Safety Assessment Management) 1997. *An International Database of FEPs; Safety Assessments of Radioactive Waste Repositories, An International Database of Features, Events, and Processes, Draft June 24, 1997, Version 3*. SAM-J012-R1. Reading, United Kingdom: Safety Assessment Management. ACC: MOL.19991214.0522.

Skagius, K. and Wingefors, S. 1992. *Application of Scenario Development Methods in Evaluation of the Koongarra Analogue*. Volume 16 of *Alligator Rivers Analogue Project.* SKI TR 92:20-16. DOE/HMIP/RR/92/086. Manai, New South Wales, Australia: Australian Nuclear Science and Technology Organisation. TIC: 231268.

8.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

64 FR 8640. Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada. Proposed Rule 10 CFR 63. Readily Available.

64 FR 46976. 40 CFR 197: Environmental Radiation Protection Standards for Yucca Mountain, Nevada; Proposed Rule. Readily Available.

AP-3.10Q, Rev. 2, ICN 0. *Analyses and Models*. Washington, DC: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000217.0246.

AP-SI.1Q, Rev. 2, ICN 4. *Software Management*. Washington, DC: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000223.0508.

DOE 2000. *Quality Assurance Requirements and Description*. DOE/RW-0333P, Rev. 9. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19991028.0012.

Dyer, J.R. 1999. "Revised Interim Guidance Pending Issuance of New U. S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999), for Yucca Mountain, Nevada." Letter from J.R. Dyer (DOE/YMSCO) to Dr. D.R. Wilkins (CRWMS M&O), September 3, 1999, OL&RC:SB-1714, with enclosure, "Interim Guidance Pending Issuance of New NRC Regulations for Yucca Mountain (Revision 01)" . ACC: MOL.19990910.0079.

NLP-2-0, Rev. 5, *Determination of Importance Evaluations*, Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981116.0120.

NRC (U.S. Nuclear Regulatory Commission) 1998a. *Issue Resolution Status Report Key Technical Issue: Total System Performance Assessment and Integration*. Rev. 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.19990105.0083.

NRC 1998b. *Issue Resolution Status Report Key Technical Issue: Container Life and Source Term*. Rev. 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.19990105.0081.

NRC 1999a. *Issue Resolution Status Report Key Technical Issue: Thermal Effects on Flow*. Rev. 2. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.19991021.0156.

NRC 1999b. *Issue Resolution Status Report Key Technical Issue: Evolution of the Near-Field Environment*. Rev. 2. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.19990810.0640.

NRC 1999c. *Issue Resolution Status Report Key Technical Issue: Unsaturated and Saturated Flow Under Isothermal Conditions*. Rev. 2. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.19990810.0641.

NRC 1999d. *Issue Resolution Status Report Key Technical Issue: Structural Deformation and Seismicity*. Rev. 2. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.19991214.0623.

NRC 1999e. *Issue Resolution Status Report Key Technical Issue: Repository Design and Thermal-Mechanical Effects*. Rev. 2. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.20000306.0670.

NRC 1999f. *Issue Resolution Status Report Key Technical Issue: Radionuclide Transport*. Rev. 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.19991214.0621.

QAP-2-0, Rev. 5, ICN 1. *Conduct of Activities*. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991109.0221.

QAP-2-3, Rev. 10, *Classification of Permanent Items*, Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990316.006.

Reamer, C. W. 1999. "Issue Resolution Status Report (Key Technical Issue: Igneous Activity, Revision 2)." Letter from C.W. Reamer (NRC) to Dr. S. Brocoum (DOE), July 16, 1999, with enclosure. ACC: MOL.19990810.0639.

YAP-SV.1Q Rev. 0, ICN1. *Control of the Electronic Management of Data*. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991008.0209.